

UNDERSTANDING BILINGUAL MESSAGES:  
THE CONCEPT OF THE LANGUAGE SWITCH

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## 1. Introduction

"To have one's own language  
is the root of human dignity."  
Aristotle

It has now become the tradition in the literature of bilingualism to begin general surveys with a view of the world, its peoples and languages. The custom was initiated by Arsenian (1937) who began his thesis reflecting on the multitude of languages and the many points of contact among their speakers. He estimated the number of known distinct languages (excluding dialects) at 1500. Most of these languages had come into contact with many others. The day-to-day traffic between speakers of different languages had produced the phenomenon of bilingualism.

In his second look at the situation Arsenian (1945) noted that the number of languages had continued to grow, as had the extent of bilingualism. Rather than forgetting their mother tongue people who found themselves in new countries as a consequence of border shuffles or immigration attempted to preserve their identity and individuality by maintaining their own language beside the new one. Arsenian suggested that bilingualism is fostered by two social/political tendencies. The principle of self-determination encourages people to keep their national language and, when necessary, even resurrect old and nearly forgotten languages like Gaelic and Hebrew in the new countries of Eire and Israel. At the same time the increased need for international communication introduces second languages which become the lingua franca for large geographical areas.

Macnamara (1967a) added another cause, the growing need of developing countries for languages that can deal with new concepts introduced by recently acquired technology, increased commerce, and modern government administration. Many of these countries are multinational (India, for example) and so political reasons are often behind the introduction of a new official language, rather than adoption of an indigenous one over others.

Today the situation is the same. The number and size of bilingual communities continue to increase. Mackey (1962) wrote that bilingualism is a temporary phenomenon, dependent on the existence of two language communities, that disappears as soon as the formerly bilingual group becomes self-sufficient. But it seems that in the world today no community can become self-sufficient enough to be able to homogenize its speech: it would be to its disadvantage to lose the educational, cultural, and economic benefits of close communications with others.

With all its advantages on the international level, bilingualism presents serious problems within a country. Here we are not concerned with the political struggle over languages, for example, in Canada, nor with the social friction between minorities and established groups in the United States. There are questions about the education of bilinguals in their second language, and about the personal psychological adjustment of people in linguistic minorities, that still remain to be answered. It is hoped that experimental psychology will contribute information useful to educators and social psychologists in the field.

What are the advantages for the experimental psychologist in the study of bilingualism? There are two areas where insights can be gained. The process of becoming bilingual, that is, the acquisition of a second

language permits observation of the learning process in more detail than in the infant's development of speech: the learner already has one mode of verbal communication against which the acquisition of the other may be measured, step after step.

The other, more general, source of benefit is the information about cognitive processes: the observation of thought through language. Just as the relationship between sensation and perception could be studied in psychophysics especially fruitfully when comparisons could be made across sensory modalities, the existence of two language systems serving the same thinking unit enables the experimenter to trace the flow of information through the thinking system by comparing one communicative mode with another. By alternating between languages for both stimulus and response the investigator can effectively "separate for study the mental processes used in acquiring or manipulating information from the information itself" (Kolers, 1968, p. 84).

### 1.1 The bilingual's language use

In a linguistically mixed environment the bilingual may be called upon to use one language exclusively, or to alternate between two. He may be addressed in either language and expected to respond in the same. Or he may be required to listen in one language and speak in the other when translating. Fluent bilinguals are usually quite successful in expressing themselves in either of their languages without mixing them up. Observing their performance it may appear to us at first that the thought processes which underlie language use are duplicated and organized separately for each language.

The generally accepted explanation for linguistic independence, or the separation of languages in speech, has been that the bilingual possesses two independent language systems from which he selects to produce speech appropriate to his audience. Penfield (1959) suggested that the act of selection is a conditioned response: hearing one language, the bilingual automatically switches to that language to answer his interlocutor. This "single-switch" model, however, did not explain how it was possible to use two languages at the same time, for example, in simultaneous translation, and could not account for cross-language intrusions. Macnamara (1967b) substituted a "two-switch" model: here the comprehension and production functions are separated, and each is controlled by a switch. The switches being independent, it is then possible to listen in one language while speaking in another (inasmuch as one can listen and speak at once in one language).

There are situations, however, in which the switches that keep languages apart do not seem to function. (Of no interest here is the output switch that is often faulty enough to permit a foreign accent or an incorrect word to appear in speech.) It appears that languages are not separated in comprehension: when two competing messages are presented in different languages there is considerable interference between them (Treisman, 1964a; Lawson, 1967). The extent of semantic intrusion indicates that possibly both messages are fully comprehended and whatever separation is observed occurs only in response selection. This phenomenon is interpreted to infirm the hypothesis of the two-switch model. The offered alternative is the basis of the present research; the hypothesis (to be elaborated further) states that only output processes are language-specific, and switched as such; comprehension is largely alingual; it has some

language-specific processes (e.g., for grammatical analysis) but its nature is really determined by the reliance on a non-verbal concept memory.

## 1.2 Statement of purpose

### 1.21 The topic

The process selected for study is comprehension. Through it I shall attempt to answer two questions.

Firstly, how language-bound is thought; how much does understanding depend upon the linguistic form of the message?

Secondly, do bilinguals employ different processes to understand messages in different languages, and if so, does the changing of these processes affect their performance?

Answer to the first question may come from results of experiment with learning/recall paradigms. Information is input in two languages; the type and the amount of recalled material should indicate the dependence of memory on language. Others have reported the results of extensive investigations in this direction, reviewed in a latter chapter of this paper.

The second question may be answered after observing the time requirements of comprehension processes for different languages, and especially the increases in processing time caused sometimes by the mixing of languages in input. Several such studies have already been made; the present research has attempted to resolve some of the contradictions in the reported evidence.

The general idea given in the title can be expanded by briefly stating the measure employed and the method: correct responses are taken as signs that the message was fully comprehended; the latency of responses is the measure by which performance (i.e., processing speed) is gauged; comparisons will be made between responses to unilingual messages and responses

to stimuli in which language change occurs.

### 1.22 Limitations

In terms of its depth and breadth this study is placed between two larger problem areas: (1) the social/personal aspects of bilingualism and (2) the perception of language.

In the first case the main interest is the use of language change, of code switching, as a mode of communication available between two bilinguals (cf. Gumperz, 1967, 1970). Code switching is voluntary but determined by social/personal factors, and restricted by semantic and syntactic limitations. Since the hearer is familiar with these factors the comprehension of mixed messages in a conversation involves the coping with expected language changes. The concern of this study, however, is the processes involved in handling forced language changes.

No attempt is made to give detailed accounts of the sensory/perceptual processes. Such treatment would demand descriptions of the steps in decoding and recoding, from the sensory to the cognitive level, and of the nature of internal representation. It is outside the scope of this paper to provide even a cursory review of the hypotheses on speech perception in terms of physical stimulus features (e.g., Halle and Stevens, 1964; Liberman, Cooper, Shankweiler, and Studdert-Kennedy, 1967). Also, to consider more central aspects, it would serve no purpose to discuss the merits of largely speculative notions about internal representation and mediating mechanisms. The comprehension process is described here in a schematized form, referring to hypothesized components, such as memory network, buffer, and the like; the main concern is with the information-processing function and not with the actual mechanism supporting it.

References to the other part of language use, production, are limited. Linguists have made the assumption that the same grammar system serves in both the generating and the understanding of sentences; psychologists have found neither empirical support, nor sound theoretical basis for this notion. Quillian (1968) argues that the use of the same grammar system for both input and output would necessitate "analysis by synthesis" for comprehension; yet, the hearer need not know by what rules the speaker constructed his message: he may discern the meaning by whatever available means. There is no evidence to suggest that language input and output processes are alike or even in symmetry; therefore, the application of knowledge of one to the other is futile and may be quite misleading.

Finally, practical considerations limited the choices of languages and the mode of presentation of stimuli. Only French/English and Spanish/English bilingual subjects were used, and all stimuli were presented visually. While the research would have been greatly enriched by data from grammatically more distant languages, and from cross-modal comparisons, the logistical difficulties precluded a more elaborate design.

### 1.23 The plan of approach

In the first part (Chapters 2,3, and 4) I shall review findings interpreted as evidence for non-verbal cognitive processing. The material is organized within the framework of a language processing model, described in Chapter 2. Several predictions are based on the features of this model; those about the storage of verbal and non-verbal information (names and concepts) are tested against the data from prior investigations in Chapter 3. Bilingual performance--comprehension of mixed input--is discussed in Chapter 4, comparing the ways the two-switch and the present model account for the evidence.

The second part begins with an introduction of the hypotheses in Chapter 5, summarizing the conclusions made during the review, then stating the assumptions and proposing tests. Chapters 6 and 7 are the reports of two experiments; each begins with a statement of its specific hypothesis, then describes the method and results. The general discussion and conclusions are given in Chapter 8.

## 2. A language processing model

I shall propose a working model of information processing and storage that describes the comprehension of speech. It does not purport to be a definitive account of language use, nor a formal model of bilingual behavior. Its primary purpose is to provide an organizing framework for the reviewed literary material and, wherever possible, to help resolve the contradictions between findings. As well, I shall derive from the model some predictions, some of which are supported by prior evidence, others only by reasoning; some of the latter will eventually be presented as testable hypotheses.

This chapter consists of the outline of the model and descriptions of its components. For the sake of consistency the model will be presented first with all of its details: its assumptions will be related to evidence in the next two chapters. The reader is asked to reserve judgment on the various assumptions until the experimental data are presented in their support. Citations in this outline are only in acknowledgement of the source of an idea, or to indicate a point of correspondence between this model and another hypothesis. Where no references are made to the literature the statements made are believed by the writer to be original formulations. I shall take responsibility for the organization of outside ideas to serve my purposes, realizing at the same time that the theoretical basis incorporates many views too generally accepted to be credited to specific sources--to writers who may object to this use of their thoughts.

## 2.1 The model

Linguists distinguish three main functions in the processing of verbal information: (1) the semantic, (2) the grammatical, and (3) the lexical. The semantic function deals with the cognitive content of an utterance. The grammatical function, subsuming syntax and morphology, is involved with the linguistic, formal aspects of speech: sentence structures and word forms. The lexical function establishes correspondence between the formal aspects of words and their cognitive content. The model contains two major systems to which these functions are assigned. The Cognitive System is responsible for the semantic function, the processing and storage of information on the cognitive level. The Code System contains the formal aspects of speech. Both systems perform the lexical function.

### 2.11 The Cognitive System

To a linguist the determination of meaning is limited to the information directly given in the verbal material; to a psychologist speech is but one information carrier among several. In listening we do not solely rely on the information given in the immediate input but use much of our knowledge of the world. (This notion has not been the linguist's concern, yet the idea pervades modern psychology and philosophy. For a definitive statement of the philosopher's view cf. Polanyi's "tacit knowing" (1967)). For full comprehension input has to be interpreted in relation to existing information. The resulting cognitive interpretation contains more information than what the input could yield to simple linguistic analysis: it has assimilated background information which was used in the perceptual process. Evidence that this in fact happens can be found in findings of

more information "recalled" than given. Bransford, et al. (1972) reported that their subjects falsely remembered sentences that contained information not in the original input but derivable from it and its context. Collins and Quillian (1970) also found that subjects used information from previous stimuli in the verification of sentences, and Barik (1970) described how skilled interpreters added material in simultaneous translation.

The Cognitive System consists of a long-term Concept Memory which holds all the accumulated knowledge, and of the processes that perceive, interrelate, store, and retrieve information from any source, and which serve among other things in the comprehension of speech.

Representations. The physical nature of representations in the brain is not the concern of this paper. Although the model's properties may imply a reliance on associative neural networks (e.g., Hebb, 1949), there will be no attempt to elaborate a physiological mechanism.

The cognitive representations in the mind stand for experiences with the world, but are removed from the patterns of sensory stimulation from which they were derived. That is to say, cognitive representations are the results of perceptual processes, more like conclusions about sensory events than records of the events themselves (cf. Pylyshyn, 1972a; 1972b).

Associative structures and concepts. Among cognitive representations that are similar, or that frequently occur together, associative bonds may form (cf. "conceptual identity" in Hebb, 1949; p. 132, and "integration principle" in Osgood, 1963; p. 258). Clusters of representations with relatively stronger associations within the cluster than outside it form an associative structure. A coherent whole, which may be

processed as a single item of information, the associative structure is a higher-order cognitive representation. It must be remembered that cognitive representations do not stand for things, but rather describe them in terms of cognitive distinctions, or features. Thus the associative structure is not the representation of a set of things, but of a set of features which define a set of things. For example, let us ask, how does one know an apple? The memory of an apple is not a record of sensations like red, round, shiny, but a set of defining features like redness, roundness, shininess, abstracted from the sensations during repeated experiences. What happens when a green apple is encountered? Since almost all of the defining features of it are identical to those in the associative structure for apple, the green kind will be recognized as an apple. Note that the recognition process implied here is the comparison of two associative structures: one defining the example, the other the set of APPLES. A sufficiently close match of features is the basis for the acceptance of the experienced object as one of the things defined by the stored associative structure. The odd feature, in this case the greenness of the apple, is also integrated in the structure by virtue of its being associated with the other, matching, features; the new feature is added to the defining color features to mean that apples may be red or green. The inclusion of new features depends upon the frequency of their occurrence, and the range of their deviations. Blueness is not an apple feature; although it is possible to find a dyed apple, the associative structure will not integrate such idiosyncrasies as defining features.

On a more formal level of description the Cognitive System may be said to contain concepts. A set of defining features could unambiguously describe the instances of the defined set, could be used to decide whether

a thing is an instance, or to generate further instances; in sum, the set of features is the concept.

Words, names, meanings. In listening to speech, a word is experienced as a special sensory event. The sound of a word does not contain information except about itself and the concept WORD. However, the cognitive representation of a word can be integrated in an associative structure which defines an object. Then the word becomes a defining feature of that object and, generalized to its set, the word will be the name of a concept. In comprehension information about a set of objects has been made available through the association of the cognitive representations of the set and of the naming word (cf. Braitenberg, 1967).

A concept may have several names: synonyms in the same language or translation equivalents of two languages. These names each refer to slightly different contents of the same concept; the word-meanings are limited and have imperfect overlap. Thus words with hypothetically identical meanings actually name slightly different concepts (or activate somewhat differently bounded segments of the associative structure that underlies the same general concept).

The organization of concepts and names. The place of a concept in the Cognitive System is circumscribed by the way its features associate it with others. The network of associated concepts is referred to as the cognitive level of organization--the base of the Cognitive System. Words and names are related on the formal and the semantic levels.

Words-as words are contained in the general concept, WORD. There are subsets defined by phonic or grammatical distinctions. The phonic distinctions derive from the physical properties, sound, stress, length, etc. Grammatical distinctions define words as parts of speech. Words

are invested with features that reflect their usual positions in speech, and the usually attached prefixes and suffixes; these are syntactical and morphological features that define grammatical classes.

A third type of distinction, the lingual, is a special case of phonic and morphological subsets. Certain general characteristics in the sounds or forms of words distinguish them as belonging to one language or another (e.g., /r/ is found only in English; vowel harmony is only characteristic of Turkish, Finnish, and Hungarian words).

In sum, the phonic, grammatical, and lingual distinctions are the basis of word organization on the formal level that exist only within the general concept of words.

Words-as-names are most closely associated with the concepts they denote, yet the correspondence is imperfect. The names actually refer to a certain part of the whole concept, to a narrower "socially standardized concept" (Carroll, 1964). The meaning is narrowed during a so-termed standardization process which takes place in person-to-person communication. Here the meaning of a word is not established by direct object references; rather, the meaning is circumscribed by references to other words, i.e., names of related concepts. Thus, meanings are standard concepts, based upon but not fully evoking the totality of the concept. There is a difference, then, in their organization: meanings follow the lines of organization of the cognitive level but on a different, abstracted plane. The names--the words that stand for meanings so organized--are associated with each other on the semantic level. The distinction between the cognitive and the semantic levels is illustrated very clearly in Head's description of semantic aphasia as the "lack of recognition of the full significance of words....apart from their immediate verbal meaning" (1926,

vol. 2, p. xix); in such cases the connection between the cognitive and the semantic levels, i.e., the concept and its name, is not fully established.

To summarize the essential differences between levels of organization: (1) the formal aspects of words are considered only within the set of words-as-words, and do not affect cognitive organization; (2) words-as-names are related to each other both through their named concepts on the cognitive level, and meaning-to-meaning associations on the semantic level; and (3) semantic organization may be isomorphic with cognitive organization but not identical to it. The rationale of word-association studies is that explicit verbal behavior may serve as a model for the implicit thought process (Deese, 1965), but it cannot be assumed that concept-associations are wholly reflected in word-associations.

Structures and processes. The structures and processes in the Cognitive System are characterized by their integration, or at least close interaction, with the Concept Memory, and by the emphasis on the cognitive content of the speech input. It is one of the important assumptions of this model that information is extracted from speech by mainly cognitive processes (i.e., conceptual) which are controlled by contextual constraints which, in turn, are applied on the basis of already stored information in the Concept Memory. A similar, strongly "non-grammatical" argument was tendered by Quillian (1968) based on the common experiences that people understand sentences with wholly incorrect grammatical structures, that they understand more complex sentences than they are able to produce, and that they can output (we "hear faster" than speak). Quillian stated that grammar is an integral part only of the speech producing mechanism and not of understanding. The present model adopts this hypothesis.

A flow diagram of the perceptual mechanism is given in Figure 2.1. The first structure is the Sensory Memory, a very short-term store, the contents of which decay in about 2 sec or are bumped out by new input. The Sensory Memory is shared between the two major systems. It serves as a "work area" in the Code System where the complex sensory pattern is converted to representations of the essential distinctions of the stimulus. The Sensory Memory also functions as an iconic memory, buffering the Cognitive System. In the next structure, the Working Memory, information may be retained from a few minutes to hours. It is only functionally distinct; in terms of information flow it is integrated with the Concept Memory. Thus when the representation of a word is entered in the Working Memory it may be directly related to any stored information.

Recognition process. The recognition process consists of attempts to integrate the defining features of the word to be recognized within the associative structure that represents a stored concept. The process is governed by both linguistic and non-linguistic information: the probabilities of the word's physical features (Osgood, 1963), occurrence in the context of preceding and predictably following information (Morton, 1969; 1971), the nature of previously perceived words (Broadbent, 1964), the social context (Hymes, 1972), and so on. The word is juxtaposed with the most likely concept in memory. If the phonic features of the word are associated with the phonic features of the name of the concept, then the word is recognized as the name. If the first match fails, new strategies are introduced. While the search continues through other likely concepts the Phonological and Grammatical Processors are also activated. The Phonological Processor modifies the representation of the word in the Working Memory to conform to accepted patterns. For example, on the phonemic level it shifts an

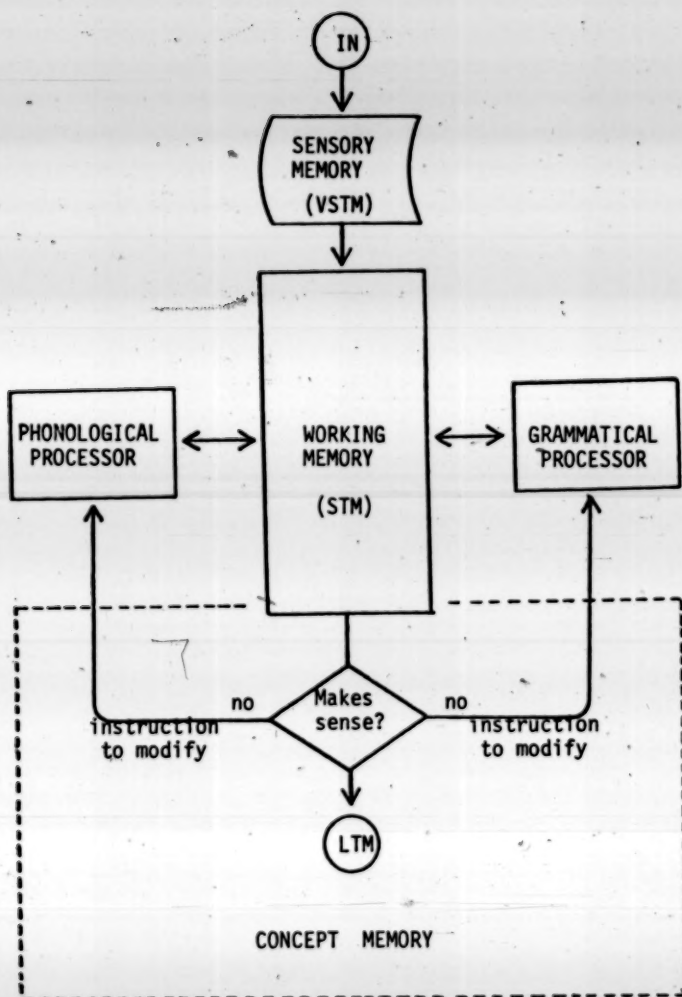


Figure 2.1 A flow diagram of the recognition process

extreme positional variant toward the median of the distribution of variants. The modified representation is tested for a match in the Concept Memory. The Working Memory holds only the last version of the modified representation. When a match is found--the name is recognized--it is the end product of this correcting/standardizing process that is retained in the Concept Memory. The original message may not be retrievable after a while since its formal aspects were not retained; it is possible, however, to reconstruct it by activating the name via its concept.

The situation is analogous to that in the recall of a visual stimulus that has undergone some correction in the perceptual process, following Gestalt principles: a circle with a small gap is likely to be recalled as a perfect circle, unless the subject is instructed to encode the peculiarities of the stimulus.

The Grammatical Processor operates on phrases or sentences. The initial, tentative interpretation of the message is in the form of a string of activated concepts which is best represented by the simplest kernel/sentence. In order to verify the hypothesized content of the message against the input the original sentence has to be transformed into a kernel sentence. As well, ungrammatical phrases must be put into some acceptable form before they can be tested as probable, or at least possible, messages.

The mode of operation of the short-term stores accounts well for data on the recall of words or sentences: the formal aspects of speech input are lost as a function of elapsed time and subsequent input. For example, the language in which a message was heard is often not recalled while the meaning of the message is (Kollers, 1966b); sentence structures are only imperfectly recalled and the number of errors can be predicted from the number of transformations necessary to reduce the input to its

kernel (Bregman and Strasberg, 1968; Mehler, 1963; Miller, 1962). The operation of the model also predicts that only actively processed information which is integrated into the store on the cognitive level may be retained permanently. Wickens (1972) and Posner and Warren (1972) review evidence about the subordination of formal features to cognitive (and semantic) both in their use in processing and in the length of storage.

Comparisons with other models. The Cognitive System, as modelled here, shares several features with other memory models which also perform recognition functions besides storage. It corresponds most closely to Feigenbaum's (1970). The arrangement of storage areas in his model (Immediate Memory, Acquisition Memory, Permanent Memory) is identical to the one described above. The crucial difference is between the operations of the Acquisition Memory and the Working Memory. Feigenbaum's "work area" contains a discrimination net through which the stimulus object is tested for various features and a representation is built for it. There is no facility for the modification of input during processing. The two memories are similar in the sense that both are extended into long-term memory which provides the cognitive base for perceptual operations. The assumption that the recognition process begins with a memory search for similar items, and then continues with likely matches which are then tested through grammar, was made by Quillian (1969) to account for semantic processing. Also limited to the semantic level of organization is Kintsch's (1970a) model; his concepts of the lexical field (where words-as-words are grouped according to formal aspects) and the associative field (where words are grouped by meaning) well describe the nature of organization on the formal and the semantic levels, respectively, in this model.

## 2.12 The Code System

It has been assumed here that the understanding of speech is a process involving mainly the Cognitive System. The primary role of the Code System is speech production; its function in comprehension is to convert sensory input into some form of internal representation upon which the comprehension processes will operate. Preliminary analyses of the stimulus input occur before any information reaches the Working Memory. These "pre-attentive processes" (Neisser, 1967; p. 213) are not specified by function, nor by location; some may occur in the sensory organs, others in the Sensory Memory, or during transfer. A crude analysis discriminates speech signals from irrelevant sources (cf. the stages of filtering in Broadbent, 1958; and Treisman, 1964b). Two kinds of hypotheses have been offered to account for the recognition of speech by sound. An active, pattern-generating model was proposed by Halle and Stevens (1964), a somewhat cumbersome mechanism which synthesizes speech internally and then matches the input signal to the generated known phonemic patterns for recognition. An alternative, passive system (Morton, 1970) relies on a "primary auditory analysis" for pre-perceptual processing, and on feature-counting "logogen" units for the correlation of sound to meaning. It is not feasible, however, to expand the present discussion to detail the actual steps involved in the converting of sensory input into representations. It is simply assumed that after some pre-processing of the sensory pattern its distinctive features are transmitted for subsequent decoding until the Cognitive System may begin to search for names.

### 2.13 The lexical function

A lexical item is the sound, word, and name, in one. That is, it may be accessed by its formal or semantic or cognitive aspect, depending on the task. (The cognitive aspect, association to concepts being different from association to other words, is a feature not included in otherwise similar constructs: Morton's (1970) "Logogens" and Chomsky's (1967) "lexical entries" correlate only semantic and phonological features.) The primary organization in the Cognitive System is on the cognitive level; words-as-names follow the association patterns of the concepts they denote. Consequently, in a naming task the discrete use of the lexicon means the activation of each involved concept in order to make the phonic features available for output. The stimulus object has to be recognized by matching its features with those of a stored concept.

Similar processes, performed in parallel, are involved in such tasks as verification of sentences, and of membership in a specified category. As in Quillian's (1967) semantic network, a proposition is verified by attempting to find a relationship between the concepts referred to in the sentence. For example, the sentence "A canary is a bird" is verified by the activation of the concept, CANARY, and the general concept, BIRD, which are then checked for interrelated features. If the defining features of bird apply to canary, and one of the defining features of canary is its inclusion in the general concept of BIRD, then the proposition is accepted. For purposes of illustration this process may be compared to Quillian's (1968) proposed scheme for verification: in order to establish the relationship between two concepts (e.g., that one is the other as a member of its set) two searches move through the memory network until their paths intersect.

A similar search-by-name takes place to verify category membership. It is important to remember that it is not the names that are associated with each other but their concepts; thus, a search-by-name implies only that the names must be entered first and when their concepts are found then the relationship is verified on the basis of concept features. Meyer (1970,1971) brought support for a similar hypothesis, postulating that a search through category names must precede accessing attributes, and that the name search is not selective since names do not contain information in themselves about set relations. The present model also states that the only defining feature a word has on the cognitive level is its function as a name of a concept.

## 2.2 Summary

The model is proposed as means to analyze the questions about language comprehension in terms of information-processing systems. It has been designed to test the hypothesis that thinking, i.e., information processing on a cognitive-conceptual level, is language-free, and that lingual differences exist only on the formal level of speech, i.e., in its phonic and grammatical aspects.

The Cognitive System. Speech is comprehended by means of a perceptual process which attempts to match input with stored information. General context directs the process to the most likely items in Concept Memory. There the input word may be identified with the name of a concept. If the match is not successful, the input word is modified toward the standardized values of the formal aspects of the most probable names. Once the word is found to be the name, the concept is activated. Information is retained in the long-term Concept Memory as new associations

between activated concepts. The formal aspects of the word are retained only in short-term memory; without special encoding the formal aspects decay with time, or are obliterated by new input. The Cognitive System is organized primarily on a cognitive-conceptual level which is paralleled by the semantic level (the name-to-name associations of limited concepts); formal aspects only differentiate words as instances of the concept, WORD, and not their named concepts.

The Code System. The comprehension process is preceded by a pre-attentive analysis of the input: it is primarily based on the physical features of the stimulus. The conversion of the sensory input into internal representations, and the subsequent identification of these as words are not accounted for in this model. The recognition of words as names occurs in the Cognitive System.

### 3. The storage of names and concepts

In the following I shall review experiments the findings of which are relevant to the question about the organization of memory: how does language affect the storage and retrieval of information that was input verbally?

The features of the Cognitive System in the model, and especially those of the Concept Memory, yield a set of predictions. It is proposed that information is stored and interrelated in conceptual form which is non-verbal (and therefore ailingual), while being accessed via the names of concepts. The predictions, then, are:

- (a) concepts and their names are not stored separately by the language of the names;
- (b) information is interrelated via associations between concepts, regardless of the language of the names;
- (c) the capacity to learn and recall is limited by the storage capacity for concepts, not names.

Furthermore, since a concept may be accessed by several names which may have been learned in different contexts the names may not be associated with the concept equally closely. Thus,

- (d) the same information may not be equally accessible by all the names of the same concept.

### 3.1 Information in a concept memory

#### 3.11 Separate versus shared storage

Kolers (1963) investigated whether information is coded in the language in which it was received and stored separately, or coded without regard to language and held in a single store. In this experiment bilingual subjects were asked to give single free association responses within and across languages, i.e., to respond in English and in their native language to stimuli in either language (four experimental conditions). Only about 30% of interlingual associations were translation equivalents: subjects tended to give different responses to the English name of a concept from its equivalent in the other language. Kolers concluded that storage was organized in memory by language groups and its form was not an alingual image.

A partial replication by Dalrymple-Alford and Aamiry (1970) also yielded different associative structures in the different languages. There was a control condition introduced: some of the subjects were asked to associate a second time to the same set of stimuli and in the same language, at which time they gave different associations. Discussing these results, and those of Kolers (1963), the authors suggested that response variability may have accounted for the differences between associations (unilinguals tend not to respond the same way to the same word twice), and concluded that neither experiment provided information about language-specific storage. The prediction about shared storage is not refuted but needs to be considered in view of the following findings.

### 3.12 Transfer across languages

Newly learned material may be utilized in a different language. Using list and paired-associate learning paradigms Young and Saegert (1966), Young and Webber (1967), and Young and Navar (1968) investigated transfer between languages. They reported that the learning of lists of single items, or of paired associates, in one language facilitated the learning of the same material translated into the other language. Both positive and negative transfer were demonstrated: a list of paired associates was learned in English (or Spanish), then either the same list in translation words differently paired were learned in translation; the same-pair list was learned in significantly fewer trials than a control list of new pairs, while the re-paired list took significantly more trials than the control. The re-learning of the first list was also negatively affected by the intervening re-paired list but not by the control. Similar effects were found in the learning of lists of single items when the second lists were in same or different order.

Kolers (1964) suggested that cognitive operations are language specific. He trained bilingual subjects to name the letters of the alphabet in reverse order, then tested them on the same task in a different language. The data showed that amount of transfer increased with phonetic similarity between languages (English, and German, French, Arabic, Korean, or Thai). To account for this result he argued that rather than cognitive operations transferring, the improvement was due to learned skill in responding. However, Dalrymple-Alford (1967) reported positive transfer in a different task in which subjects had to name the letter preceding a stimulus letter in the alphabet; he criticized Kolers' method of conditioning response sequences and suggested that his own method demanded cognitive, not only

response, skills. In view of Young's results (above), indicating transfer effects in list learning, one may conclude that Kolers' subjects actually learned response sequences and not new cognitive operations. Whether the task in Dalrymple-Alford's experiment involved cognitive or response skills is not relevant to the conclusion from this evidence: the learning of new associations (lists or pairs) and of skills is transferable between languages. This argues against the separateness of storage for verbal material.

In these studies it was assumed that names and concepts are stored together, that is, the representation of a language-bound name is inseparable from the representation of a concept. This assumption, and that of separate storage itself, lack relevant evidence. The notion of separate storage arose from the misinterpretation of the principle of compound/coordinate organization of languages. Weinreich's (1954) definition holds that if two signs--one being a word in one language, and the other its translation equivalent in the other language--have the same meaning, then each word is a "compound sign" and belongs to a "partially merged," or compound language system. If the translation equivalents have different meanings, then they are "distinct signs" and belong to separate, coordinate language systems. Lambert, Havelka, and Crosby (1958) proposed that the two types of organization originated from different modes of second-language acquisition. In "fused" acquisition contexts the bilingual's community uses both words (from two languages) to refer to the same stimulus object or event; the signs become interchangeable since their referents are identical. If the languages are acquired in "separated" contexts, i.e., in different linguistic communities, then the translation equivalent words will be associated with different

experiences, and thus connect to different concepts. But the classifying of bilinguals as compound or coordinate types has been the source of strong controversy, chiefly because of the recognition that within one person's vocabulary both organizations may exist side by side, in different semantic areas. Furthermore, the organization types are constantly changing with experience; Ervin and Osgood (1954) predicted that with translation practice (in which two signs are repeatedly used in the same context) the original differences in connotation will diminish, and the previously coordinate system will change to compound.

In the cross-language association studies the findings of differences in associations between two languages were interpreted as evidence of separate storage systems; in fact, the differences may well have been due to the semantic distances between words in a coordinate organization, i.e., differences in meaning between translation equivalents. The evidence cannot be accepted as relevant to the question about the organization of long-term memory, and used to reject the hypothesis of a common storage for words.

### 3.13 Storage by concept

Several studies showed that the amount of information retained is determined by the system's capacity to store concepts, not names.

Kolers' (1966a) subjects were tested on recall of lists of words. The Translated List consisted of 120 words, of which 100 were repetitions of 20 English nouns and their French translations, and 20 fillers. The Non-translated List was similarly constructed but there were no translations. Thus, the Non-translated List contained 40 concepts (through the 20 English and 20 French names), and the Translated List only 20, since

the translations referred to the same concept. The proportion of correctly recalled words from the Translated List was twice the proportion of the Non-translated. Since the proportion of recalled words was found to increase nearly linearly with the number of repetitions (Waugh, 1963; Glanzer and Duarte, 1971), it appears that the presentation of a word in translation has the same effect on recall as repetition in the same language. Analysis of the recalled words by meaning showed that subjects recalled concepts in equal numbers from both lists. This result is interpreted as evidence that the subjects encoded the presented items on the cognitive level as alingual concepts, and were limited by the retention capacity of the Concept Memory. During recall of the Non-translated List each concept yielded the output of a single name, while in recalling the Translated List the same concept could elicit the output of two names. Kollers (1968) concluded that the input of equivalent symbols from two systems increases the access to information, indexed by those symbols, but not the amount of information that can be retained.

When the information is not repeated in different languages the number of concepts activated will be the same as the number of names. Recall then may vary with the added load of language identification. Such interpretation should be given to the results reported by Tulving and Colotla (1970) whose subjects were presented with lists of words in one, two, or three languages for recall after one presentation; recall was assumed to be from long-term memory if seven or more words--presented or recalled--intervened between the presentation and recall of an item. Best recall was from unilingual lists, next from bilingual and worst from trilingual. Since no translation equivalents appeared on the multilingual lists the number of concepts activated and made available for recall is

attributed to the demand of processing alternately several languages under time pressure (presentations were made at the rates of .5 or 2 sec per word). This experiment will be discussed in detail below since its results are more relevant to the question of differences between short and long-term memory.

### 3.14 Conclusions

- (a) If the storage and retrieval of information in Concept Memory are non-verbal then names and concepts are not stored by language; neither studies of interlingual associations (Kolers, 1963; Dalrymple-Alford and Aamiry, 1970), nor of cognitive operations (Kolers, 1964; Dalrymple-Alford, 1970) found evidence of separation by languages in memory.
- (b) Language boundaries were found not to affect cognitive processes in experiments on interlingual transfer of paired-associate and list learning (Young, et al., 1966; 1967; 1968).
- (c) Retention of verbal items was found to be limited by buffer storage capacity for concepts, and not for names, in tests of recall (Kolers, 1966a).

The predictions derived from the features of a non-verbal, therefore ailingual, Cognitive System are strongly supported.

## 3.2 Accessing concepts by name

### 3.21 Differences in accessing

That some concepts are not readily available in one of the bilingual's languages is indication of partial or remote association between name and concept. If information is input in one language it will not be available

in another language if it is to be accessed by name. More often, though, the information which leads to the forming of a concept is input non-verbally. Indeed, it may not be necessary to have names for concepts at all: "Animals and young children behave towards many things in much the same differentiated way that we do, without having names for them." (Oldfield, 1966; p. 346). Eventually, children learn to understand and produce speech, having acquired names for their concepts.

The language development of the bilingual child reflects a gradually worked out correlation between names and concepts. Imedadze (1967) reported about the simultaneous acquisition of Russian and Georgian by her daughter: the first words were not translation equivalents (each concept had only one name), but after age 1;2 equivalents appeared and were used like synonyms; until nearly 20 months of age the child's sentences were linguistically mixed and ungrammatical. The inexperienced but enthusiastic adult bilingual shows a similar pattern: he freely substitutes words from his first language for missing ones in the second.

Unlike unilinguals, bilinguals often acquire the name before the concept when they encounter an unknown word and then rely on the rest of the message to interpolate to the correct referent. Comparing 4 to 9 years old children Worrall (1970) found that bilinguals recognized more semantic--conceptual--similarities between stimulus words than unilinguals who tended to focus on phonetic--formal--similarities. Questioning the subjects she also found that bilinguals developed the notion that words are arbitrarily assigned and interchangeable names of concepts much earlier than unilinguals.

The difference between the accessibility of a concept through its name in one language and in another was utilized in the measurement of the

degree of bilingualism from response latencies (Lambert, 1955; Lambert, Havelka, and Gardner, 1959; Ervin, 1961a, 1961b).

Differential access through name or non-verbal signal was investigated in a reaction time study of Slovak-Hungarian bilinguals and Slovak unilinguals. Kováč (1967) compared latencies in selecting and depressing the appropriate key in response to either verbal instruction or colored light stimulus. There were no differences between the groups when responding to visual, non-verbal stimuli; however, unilinguals performed significantly better when instructed verbally than bilinguals (differences in bilinguals' responses to dominant or weaker language were not reported).

Macnamara (1967c) tested English-dominant high school girls who had learned French in school. The measures included recognition thresholds on tachistoscopic presentations of words and sentences, reading silently and aloud, and reaction times for true/false decisions about the match of a picture and a word projected side by side. He found no differences between languages in perceptual thresholds but significantly lower scores on picture-word matching in French than in English. The conclusion was that bilinguals code semantic values, i.e., reach concepts from names, slower when the names are in the weak language. This finding was held to account for inferior performance in problem-solving in the weaker language; processing becomes inefficient as instead of being chunked words are held for overly long times, overloading short-term memory.

### 3.22 Conclusion

Two languages may differ in their efficiency of accessing information and establishing new categories. The gradual acquisition of two names for each concept by bilinguals, and the sometimes only partial or remote

association of names and concept is reflected in the speech development of bilingual children (Imedadze, 1967; Worrall, 1970), and in reaction time studies in the measurement of bilingualism (Ervin, 1961a; 1961b; Lambert, 1955; Lambert, Havelka, and Gardner, 1959; Peal and Lambert, 1962; Kováč, 1967).

### 3.3 Summary

This chapter attempted to answer the question: how are the bilingual's languages separated--does he think in two languages? Based on the features of an information-processing model a number of predictions were evaluated in the light of reported findings. The following conclusions could be made:

- (a) Information is stored in a conceptual form and not grouped by the language of input.
- (b) Information is interrelated in a conceptual, rather than nominal, form.
- (c) Concepts, not names, are retained in long-term store.
- (d) Names are not equally closely associated with their concepts, hence the difference between languages in retrieval.

#### 4. The comprehension of mixed messages

In this chapter I shall relate the results of previous investigations in bilingual comprehension to the predictions based on the features of the alingual processing model. The problems to be examined are the following:

- (a) How are simultaneously arriving messages discriminated? The model predicts that discrimination occurs primarily on the cognitive level, i.e., regardless of the formal aspects of the input, the information is accepted or discarded according to the relevance of meaning in the task context.
- (b) What changes in processing mode are necessary to cope with messages that alternate between languages? The present prediction is that the bilingual needs to switch processes only if the input is syntactically structured. Since messages in sentence form contain information that is coded in the relationships between words, the comprehension of sentences may require the application of language-specific grammatical analysis.

##### 4.1 The discrimination of competing messages

Performance has been found to suffer from the simultaneous arrival of two messages. Typically, the experimental task is to attend to one message, the information carrier, while ignoring the second, the competing message. The processes involved here are the separation of the two messages, the recognition of the information carrier, the suppression of the competing message, and responding to the information.

This section deals with three experimental conditions: (1) shadowing one of two competing messages; (2) translating one of two competing messages; and (3) responding to non-verbal information under interference from competing verbal message.

#### 4.11 Shadowing

A cross-modal analog of the shadowing task is reading aloud. In reading, the information is received visually, comprehended in the Cognitive System and converted into intentions for speech output; the material that is being processed may be directly measured through the eye-voice span. In shadowing, the information is received aurally and its phonological aspects are supplied directly to the Code System, while the cognitive aspects are processed in the Cognitive System. The effects are two-fold. On the one hand, speech production may be performed as a direct copying of the input form, economically bypassing the Cognitive System. On the other hand, the Sensory Memory which briefly holds both the input message and the acoustic feedback from output will receive similar material within a short interval and the resulting partial overlap may disrupt performance (similarly to disruption by delayed auditory feedback, probably attributable to the breakdown of closed-loop control of articulation by acoustic feedback). The task appears impossible, yet it may be performed reasonably well by means of separate, and autonomous, input and output processes.

Shadowing one of two competing messages compounds the problems by adding another auditory input. Treisman (1964a) compared the effects of different types of competing messages. The main task consisted of repeating a text heard through earphones; this, the information message,

was a continuous passage from a novel, spoken in English in a woman's voice. The competing messages included the following in a woman's voice: a different passage from the same novel, a technical text in English, samples of prose in three languages (one fluently spoken by the listener, one known, and one unknown), a nonsense text with English pronunciation, and an English text played in reverse. A passage from the same novel in English and a mixed English-Latin text were read in a man's voice. Both the information and the competing messages were heard in both ears. Performance was rated by the percentage of correctly repeated words from the information carrier. The results, given below, are the mean percentages listed in order from best performance to worst.

<u>Competing</u> <u>message:</u>	<u>Percent</u> <u>correct:</u>
man's voice, mixed text -----	73%
man's voice, same novel -----	73%
woman's voice, unknown language ----	55%
woman's voice, nonsense English ----	49%
woman's voice, known language -----	47%
woman's voice, reversed English -----	45%
woman's voice, well-known language --	42%
woman's voice, technical English ----	39%
woman's voice, same novel -----	31%

It appears that the different voices interfered least, as did unknown language and nonsense in the same voice; most interference stemmed from similar English text, and almost as much from different English text and a well-known language. To account for the differences the author referred to a multistage perceptual process, formulated elsewhere (Treisman, 1964b): discrimination of classes of signals begins on the basis of physical characteristics, then signals from irrelevant channels are discarded, and finally words and meanings are identified from among selected signals. The first step of the process is well reflected in the good separation

of the two voices by pitch (little interference by the man's voice). It seems, however, that words are comprehended from both signals, not only from a preselected one. That is, all the intelligible words that were not filtered out as physically different are fully comprehended. This may be seen from the finding that a well-known language interfered almost as much as English, even though its words were phonologically different and thus formally distinguishable from English. It is unlikely that a multistage filtering system, if it existed, could not eliminate German, Italian, and French messages on the bases of their very characteristically unEnglish phonemes, intonation, and sentence structures. A more probable explanation would be that beyond the first crude physical sorter there is only one decision made, and that in the Cognitive System, whether the input has meaning or not. Words from unknown languages are then ignored, along with phonologically familiar but meaningless English nonsense words. Other words, however, are fully processed on the cognitive level, regardless of language, as long as they are meaningful. This conclusion is clearly in agreement with the assumptions about an alingual comprehension process.

#### 4.12 Translation

Interference in simultaneous translation creates the burden of having to cope with three different messages, two in input and one in output. Only one such study has been reported.

Lawson (1967) compared the effects of various competing messages upon translations between English and Dutch. The text to be translated was a continuous passage from a novel in Dutch, or its English translation. The competing messages included passages from the same novel and from a

different novel, in both languages, and second and sixteenth order approximations of English and Dutch. Each message was presented in one ear only. Performance was scored by the percentage of words not translated from the main message. It was found that competing messages in a different language interfered less than in the same language, similarly to the effects in shadowing. Among competing messages in the other language, different text interfered less than translation from the same novel. However, when the languages of the two messages were the same, then performance improved by hearing the same text (Fig. 4.1). The expectation had been to the contrary: interference usually increases with similarity as the filtering and rejection of the unwanted input becomes more difficult. Lawson proposed that rather than filtering, a facilitation effect should be considered. If certain dictionary units or thought units (cf. Broadbent, 1964; Morton, 1964a) had been activated by elements in the competing message, then they are more likely to be activated in the comprehension of the information message. But then similar activation should occur when similar meaning is input in the other language, if the earlier conclusions about Treisman's (1964a) results were correct. Since Lawson could not replicate her results (as reported in 1967), the issue will have to remain open.

#### 4.13 Color naming

Interference may occur in situations where verbal and non-verbal inputs compete. The phenomenon is the basis of the Stroop Color-Word Test (1935). The testing material consists of three cards: a list of words that name colors, printed in black ink, a series of color patches, and a list of color names, each of which is printed in a color other than

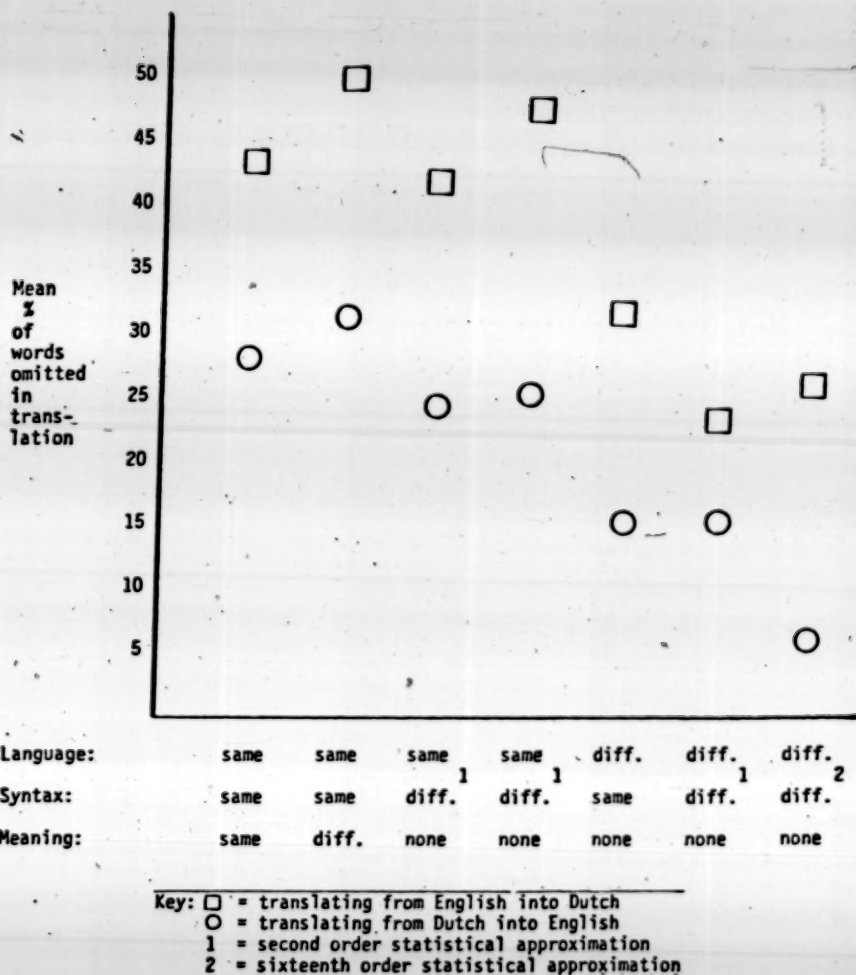


Figure 4.1 Translation efficiency in the presence of interference. The scores are ordered by distance between main and competing message in terms of language, coherence (syntax), and meaning. Based on data reported by Lawson (1967).

what is named. Subjects are asked to read the list printed in black, then to name the colors of the patches, and finally to name the colors in which the names are printed. The reading time for each card is measured. It has been found that the printed word interferes in the naming of the ink color; typical errors are the reading of the word itself, hesitation, or stopping. It is assumed that while the subject attends to the non-verbal color stimulus he can not ignore the conflicting verbal stimulus, the meaning of the color word. The following two experiments investigated the word-color interference across languages.

Dalrymple-Alford (1968) compared performance on four types of Stroop cards: color words printed in the same color they named (congruent color words), color words in other colors (noncongruent color words), non-color words, and clusters of x's as control for color naming without interference. All words were in English and had to be read in Arabic by fluently bilingual students. Performance was poorest on the list of noncongruent color words in which the names conflicted with colors. Thus, even though the words were in a language other than the responses, they were comprehended sufficiently for their meanings to conflict with the non-verbal stimuli. No interference appeared from congruent color words.

A more elaborate investigation was reported by Preston and Lambert (1969). In a series of three studies they tested bilingual speakers of English and French, German, or Hungarian. Each subject was tested in both of his languages twice, once on lists of words in the language of the response, and once in the other language, as well as on simple naming of color patches. The various comparisons included different languages, visually similar and different color names, and color names and non-color words. The results may be summarized as follows:

- (a) Color patches were named equally well in all languages.
- (b) Words printed in color interfered with color naming.
- (c) Words printed in the language other than that in which colors were to be named interfered with color naming.
- (d) Visually similar translation equivalent color words (e.g., French-English bleu-blue) interfered more across languages than visually different words (e.g., German-English lila-purple).
- (e) The most frequently occurring error in the intralingual condition (i.e., stimulus and response in the same language) was the reading of the printed word instead of naming the color.
- (f) The most frequent error in the interlingual condition was the translation of the printed word instead of naming the color.
- (g) Non-color words did not interfere with naming.

The authors concluded that while in intralingual tests interference was manifested in the reading of the printed word, the corresponding error in the interlingual tests was the translation of the word. This statement was then the basis of argument against the formerly accepted single-switch model. Penfield and Roberts (1959) had proposed that bilinguals keep their languages apart with the help of an automatic switch--a type of conditioned reflex--which allows only one language system to operate at any time. The Preston study showed that the activation of one linguistic system, by instruction to respond in one language, does not fully deactivate the other system which may continue to process irrelevant input, i.e., read and translate words on the Stroop cards.

It has been argued in several contexts in this paper that perception and comprehension of speech are not linguistically organized processes. In the light of the preceding interpretation of the findings of

Treisman and of Lawson it may be useful to scrutinize the results of the interlingual Stroop tests in a similar manner.

The bars in Fig. 4.2 represent intralingual versus interlingual interference differences. An example of the calculation may illustrate this concept:

A group of German-English bilinguals obtains the following average average scores (fictitious data):

Responding in German...

...naming color patches (no interference)	60 sec
...naming colors of German words (intralingual)	100 sec
...naming colors of English words (interlingual)	80 sec

Responding in English...

...naming color patches (no interference)	70 sec
...naming colors of English words (intralingual)	110 sec
...naming colors of German words (interlingual)	90 sec

The German differential score is  $(100 - 80) / 60 = .333$ .

The English differential score is  $(110 - 90) / 70 = .287$ .

The mean differential score is  $(.333 + .287) / 2 = .310$ .

Dividing by interference-free naming time removes the bias due to differences between languages in naming speed; the score then reflects how closely a translation equivalent approximates the interfering effect of a word in the responding language. High mean differential scores indicate large differences between intralingual and interlingual interference, i.e., that the color words and their translation equivalents are psychologically distinct. The scores graphed in Fig. 4.2 fall into two groups. The first two bars represent large differences between intralingual and interlingual interference when the words of the two compared languages are physically distinct, for example, (GD) rosa/pink, (H) zöld/green. Evidently, the color word is least likely to be read when its visual features set it apart from the language of response. The fourth and fifth bars show that differences between intralingual

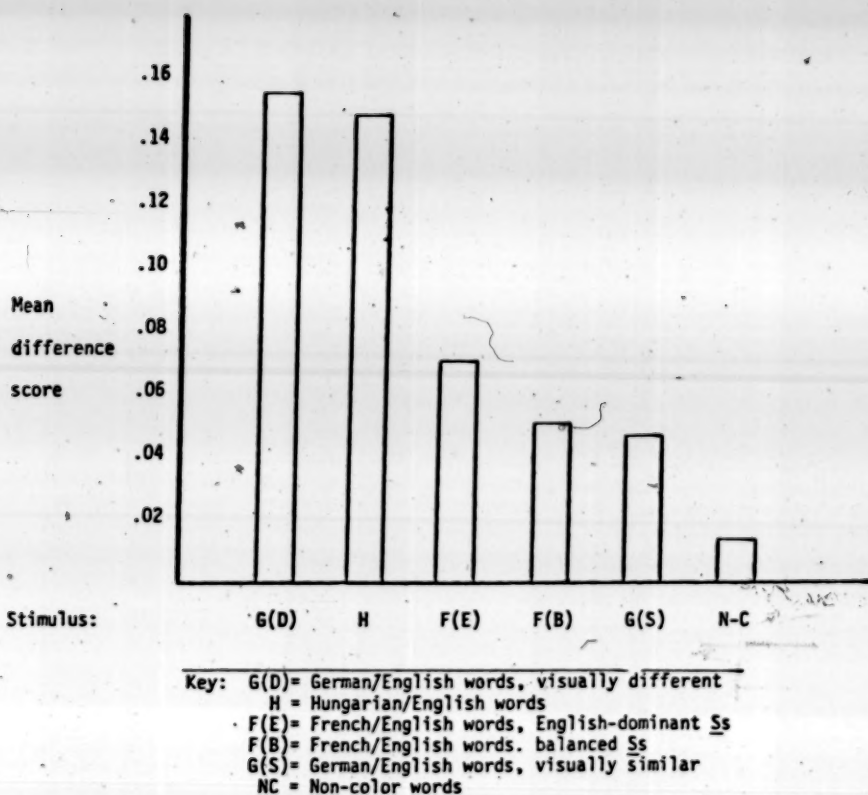


Figure 4.2 Differential interference by words in the same or other than the responding language. The mean difference scores were calculated by subtracting the shorter reading time from the larger, dividing by the color naming time (without interference) in that language, and taking the mean of the two languages. Based on data reported by Preston and Lambert (1969).

and interlingual interference are small when the words of the two compared languages are physically alike, for example, (FE,FB) bleu/blue, (GS) grün/green. Thus a color word that looks like a word in the responding language interferes with naming almost as much as the word it resembles.

The concern here is not with the efficiency of distinguishing words by their visual features, but rather with the marked inefficiency to make use of linguistic features. If the distinctness of linguistic systems were as important in comprehension as generally suggested, then the linguistic features of a word should cause it to be identified and rejected before it could interfere on the cognitive level. There is little evidence in the Preston data that such discrimination takes place.

Preston and Lambert hypothesized that interference from the other language occurred through a translation process. An alternative interpretation is Dalrymple-Alford's (1968) conclusion about his finding that congruent color words (naming the color in which the word was printed) in English did not interfere with naming in Arabic; he suggested that the English words possibly "primed" their closely associated translation equivalents in Arabic.

The explanation offered here is that the problems in color naming are caused by the conflict between two equally well comprehended messages, similarly to the shadowing and simultaneous translation paradigms. In the Stroop test one message is non-verbal, the color, the other is the word; if the two are not the same then two different color concepts will be activated in the Cognitive System, resulting in confusion as to which is intended for output. In the case of a congruent color word there is, of course, no ambiguity and consequently no interference with naming; on the contrary, one could expect to find facilitation.

#### 4.14 Conclusion

Three tasks in which interference occurs, that is, shadowing or translating one of two messages, and naming the colors of words, are assumed to be identical in principle. The demand is to respond to one of two or more selected messages. There is little discrimination between the competing messages by their formal aspects. Both messages are processed in the Cognitive System; consequently, concepts will be activated regardless of the language of their names. If the resulting information items are in conflict, then performance will deteriorate since several incompatible intentions may be supplied to the Code System for response; conversely, congruent information items from two messages may facilitate processing.

#### 4.2 Language switching

Possibly the most important aspect of bilingual performance is the ability to change languages. As Kolers (1968) wrote, the skilled use of two languages presumes a readiness to switch between them, and to switch completely, that is, without elements of one language intruding in the other. The total changeover demands the change of vocabulary, grammar, and phonology. It has been generally assumed that the "two-switch model," proposed by Macnamara (1967b), describes the mechanism by which languages are both kept apart, and changed on demand, during bilingual performance.

Both Macnamara's and Kolers' ideas will be re-examined more critically in the next chapter. In this section I shall review their methods and results; although some of the cited papers reported studies of speech production as well, only the parts dealing with comprehension will be discussed.

#### 4.21 Comprehension of switched input

Kolers (1966b) tested comprehension of connected passages from short stories. Comparisons were made of three types of stimulus material: (1) unilingual text (English or French); (2) alternated text in which language changes occurred at the end of sentences; and (3) mixed text in which the language was switched within sentences. The latter followed either English or French word order with phrases inserted from the other language. Subjects read the passages silently within a time limit. Comprehension was estimated on the basis of answers on a short test and true/false responses to questions about information in the passages. Performance tended to be best in the reader's native language, less in alternated, and worst in mixed texts. There were no significant differences due to language change. A significant interaction between language groups (i.e., subjects' native languages) and text forms indicated that native syntax in mixed texts was preferred to that of the second language.

More sensitive measures were used in a series of tests by Macnamara and Kushnir (1971). The speed of silent reading was measured by having subjects indicate with a pointer the word they were reading. The materials were connected passages: English or French unilingual, and two bilingual texts, one with English and one with French structure in which phrases from the other language were inserted. Mean difference scores were computed from the observed reading times for bilingual texts, subtracted from the "composite reading time," estimated for the mixed texts from the reading speeds of each language observed in unilingual texts. Thus the mean difference scores measured how much longer it had taken a subject to read a mixed text than a unilingual one. The difference between bilingual and unilingual reading was significant in both languages; no

significant differences obtained between languages. The data also yielded an estimate of the time required to change language systems for comprehension. The additional time taken in reading mixed text was divided by the number of language changes in the text; the resulting switching time (ST) averaged 170 msec.

In the same study short sentences were presented to the subjects for verification. Responses were made by key-pressing for true/false decisions to eliminate the effects of verbal output processes. The stimulus sentences were unilingual or mixed, the latter containing one, two, or three language changes. Reaction times showed significant increases due to switching. The mean increase from unilingual to once-switched sentences was 210 msec, to twice-switched 370 msec, and to three switches in the same sentence 490 msec. The average ST of the three switching conditions was 183 msec, which is slightly higher than that for connected text. Also somewhat higher STs were obtained when similar material was presented aurally. The authors' conclusion from these results was that the comprehension of mixed input requires the changing of linguistic systems; the time taken for switching increases overall reaction time, and these switching times are roughly additive. The findings were presented in support of the postulated input switch of the two-switch model.

These results run contrary to those of Dalrymple-Alford and Aamiry (1967) who reported that mixed input does not require any longer processing than unilingual. In that experiment subjects were to respond by pressing one of six keys as signaled. The keys were specified by side, left or right, and coded by color, three on each side. The signals were given visually and consisted of two words, the side and the color of the key to be pressed. Comparisons were made between unilingual signals (both

words in English or in Arabic) and mixed signals (the languages given in both orders: English-word first, followed by Arabic, and vice versa). Reaction times to unilingual or mixed signals were not significantly different. Aside from faster responses to Arabic/English mixed signals than to English/Arabic ones all scores were similar. These data indicated that mixed input had been comprehended without having to switch between languages.

#### 4.22 Control of the input switch

The effect of anticipation of language change in input was tested by Macnamara and Kushnir (1971) in a sentence verification task, similar to the one described above. Comparison was made between random and regular schedules of switching. The stimulus material consisted of short sentences either in English or mixed English and French. Each mixed sentence contained only one change of language and was presented in two colors, the English words in black and the French in red. The subjects responded by pressing one of two keys, indicating whether the shown sentence was true or false. The mixed and the unilingual sentences were given either in a random pattern or alternating regularly. Reaction times were significantly different between the two schedules and shorter for random than for regular switching. The authors concluded that the input switch, assumed to be automatically set by signals from the pre-attentive perceptual analyzers, cannot be brought under voluntary control without interfering with its performance..

#### 4.23 Conclusion

The findings about switched input will be related here to the assumptions of Macnamara's two-switch model and of the alingual processing model. These are not alternate hypotheses; rather, the two models attempt to account for different modes of bilingual comprehension.

The two-switch model assumes that in order to cope with a language change in input a switch must be made between language systems for comprehension, and that the switch is not voluntarily controlled. The alingual processing model assumes that comprehension is generally alingual, and that language-specific processes are activated only in such tasks as sentence verification where grammatical analyses may be necessary.

The evidence for the existence of an input switch was found in the reaction time increases that followed language changes in input (Macnamara and Kushnir, 1971); however, no such increases were found by Dalrymple-Alford and Aamiry (1967). The basic difference between these experiments is that the former presented either connected passages or complete sentences in input, while the latter tested simple two-word stimuli. It appears that when the message could be comprehended without syntactical analysis then switching of language systems was not necessary. The two experiments could neither support, nor infirm the input switch hypothesis; their results reflect the differences between the processing of sentence and non-sentence input.

The possibility of voluntary control over the input switch was tested by Macnamara and Kushnir (1971). However, their method of presentation did not allow subjects to prepare to process in a specified language; it merely warned that mixed input is to be expected. Thus, it is possible that performance deteriorated due to unsuccessful attempts to

activate two different language-specific processes at the same time. No conclusions may be made about the control of comprehension processes without testing the effects of anticipation in a sentence-to-sentence switching situation, and without comparing performances in sentence-processing tasks and in tasks in which verbal input is given in a non-sentence-structured form.

#### 4.3 Summary

Two questions about bilingual performance were asked: (1) how are simultaneous messages in two languages discriminated; and (2) how do bilinguals cope with alternation of languages in input. The findings of previously reported investigations were interpreted in support of the hypothesized alingual processing model. The following conclusions could be made:

- (a) Speech comprehension is vulnerable to interference between two competing messages. Reinterpretations of data about shadowing, translating, and color naming tasks strongly indicates that the selection of the information carrier message and the discarding of the competing message are performed by alingual processes. That is, input is discriminated by its physical features during preattentive perceptual analysis, and by its cognitive features (degree of meaningfulness in the context) during its attempted integration with stored information, but not by the lingual affinity of its words.
- (b) The effect of language change in input on performance varies with the type of message to be comprehended. Increases in reaction time indicated that a changeover of language-specific processes

may take place in the comprehension of sentence-structured messages. There is no clear evidence about the effect of anticipation of language change in the reported studies.

## 5. Hypotheses about the input switch

This chapter briefly reviews some points about the phenomenon of linguistic independence and two models for bilingual performance.

Following a critique of previous explanations I shall propose a hypothesis for bilingual comprehension, based on the features of the model outlined in Chapter 2, concluding with predictions and an introduction to the present research.

### 5.1 Linguistic independence

A person fluent in two languages is usually able to speak either language without mixing it with the other. The generally accepted explanation for this phenomenon has been that the bilingual possesses two independent systems which serve in the use of language, and from which he selects the one appropriate to his interlocutor. Penfield and Roberts (1959) suggested that the mechanism of selection was a switch that automatically, in the manner of a conditioned reflex, activated one of the language systems at a time. This "single-switch" model did not account for either the parallel use of two different languages for listening and speaking (as in simultaneous translation), or for the interference between read and spoken languages (as in color naming; Preston and Lambert, 1969). To account for separable input and output functions Macnamara (1967b) proposed a "two-switch" model.

### 5.2 The two-switch model

Macnamara hypothesized that as in the production of speech a similar selection occurs in reading or listening: for comprehension the bilingual

chooses the system which is appropriate to the language of the incoming message. This hypothesis stated that the switch of linguistic systems takes appreciable time, thus each change of language in the input increases the time required for response. Several studies found evidence for the existence of the input switch in the observation that linguistically mixed messages took longer to be comprehended than what could be predicted on the basis of responses to unilingual messages (Kollers, 1966b; Macnamara and Kushnir, 1971).

It appears, however, that there are situations in which the input switch is not activated. For example, two languages may be in the input simultaneously. One would assume that if the input switch serves to select systems exclusively, as does the output switch, then while it activates one system it excludes the other. We find, though, that bilinguals do not fully separate languages in input: when two competing messages are presented in different languages there is considerable interference from the second language in the form of semantic intrusions (Treisman, 1964a; Lawson, 1967; reviewed in detail in Sections 4.11 and 4.12). It is unlikely that an input switch could oscillate quickly enough to shunt simultaneously heard English and French, or Dutch, words to the different language systems. The observed interference suggests that the bilingual does not differentiate input messages by formal linguistic aspects; regardless of language, all of the information is processed and then sorted on the basis of its relevance to the task. It is then necessary to re-examine the hypothesized and the observed features of language changes in comprehension.

### 5.3 Critique of system switches

It was implicitly assumed in the papers of Kolers and of Macnamara that language systems are switched in their entirety. That is, the various cognitive skills (lexical, grammatical, and phonological) which play parts in the processing of verbal information, and are subsumed in the functional organization of a system, all are specific to one language. The two-switch model also assumes that comprehension and production of speech are served by processes that are similar in their both being organized by language. The objections here are to the generalization of one system's features to the other, and to the concept of all-or-none switching.

Certainly, the notion that production processes are distinct for each language is a strong one. The automaticity of such a complex behavior as speech implies the presence of a highly organized and integrated response mechanism. If, for the purposes of illustration, one views the act of speaking as a motor skill, the demands upon it are comparable to those faced in athletic performance: the execution of a tennis serve, for example, is completely disrupted by any hesitation or a deviation from the engrained pattern of motion; similarly, fluent speech relies on the continuity of phonological patterns. If the continuity is violated, when the speaker is forced to switch languages, the performance deteriorates, hesitations and pronunciation errors occur (Kolers, 1966b; Macnamara, Krauthammer, and Bolgar, 1968). It should be noted here that there is evidence of intrusions from one language into the other in the speech of many bilinguals, for example, foreign accent or incorrect syntax; these errors disappear with practice, indicating that they were caused by incorrectly or insufficiently learned speech skills, and not

by the speaker's thinking in two languages. At the same time, practiced bilinguals are able to control various functions that underlie speech production separately. For example, to expand Neufeld's (1973) apt illustration and describe the performance of an accomplished multilingual: one can speak English with a heavy French accent and a Germanic syntax (each being quite distinctively inappropriate). The result will be very poor English speech but perfectly intelligible regardless. This point is the basis of the further argument that the comprehension process need not be, and probably is not, similar to production.

Comprehension utilizes extra-verbal cues to such great extents that it may be impossible to determine how much of the achieved information was transmitted in the verbal code and how much of it was gleaned from context and expectations. Thus it may be quite easy to understand a foreigner who uses the wrong words and bad grammar, providing he gestures a lot; in the case of a fluent speaker more of the information will be verbal. The difference is a matter of degree: one cannot pinpoint the switch from non-linguistic to linguistic processing since the component processes are not functionally distinct systems. It should not then be assumed that in bilinguals the language-specific members among the linguistic comprehension processes are organized in independent, and selectively activated, systems.

A major argument against all of the switch models, including the presently proposed one, will be developed in the general conclusions (Section 8.4) but should be introduced briefly at this point. The common shortcoming of the switch hypotheses is a tendency to be simplistic and to ignore the potential richness of the repertory of cognitive modes. The explanatory power of these hypotheses is limited because they are

based on the single-channel principle of information processing. The basic assumption of this principle is serial processing in systems which, when active, are mutually exclusive. In the switch models it is further implied that language changes require a single-step process, and that this process is used symmetrically whether the language change is from dominant to weak, or vice versa, and similarly under all conditions. In the course of the present research it became increasingly apparent that the prevailing models were inadequate. There were indications that language changes were not regularly followed by switching, and that on occasion other processes, in addition to or instead of switching, may have taken place. The difficulties in the interpretation of the data within the predictions of the switch models led to the eventual conclusion that the very basic assumptions in the models, and indeed in the single-channel theory, are untenable. However, since this research was conducted from the outset to investigate the proposed details of such a model, it is reported within its context; while occasional references are made in the discussion sections, an alternative approach is described only in the final chapter.

#### 5.4 Proposed hypotheses

##### 5.41 A hypothesis of separate functions

The present alingual processing model asserts Quillian's (1969) proposition that grammar is secondary in comprehension. Processing begins with a memory search for items similar to those in the input, then as likely matches are found among stored concepts a hypothesis is made about the meaning of the input, to be verified by the syntactic structure of the message. For example, the sentences "The dog bit the man" and "The

man was bitten by the dog" both have the same intention but are differently structured. They both invoke the concepts of man, dog, and biting. In processing, it is necessary to confirm on the basis of syntax that the intention was not the third possible combination of these concepts, that is, "The man bit the dog."

The structure of the stimulus material, whether it is a sentence or not, determines the choice of processes.

Word recognition versus sentence comprehension. Distinction is made between the assumedly alingual processes of word recognition and language-specific ones for sentence comprehension. The verification of the sentence "The blue key is nearer than the red" requires the clarification of the relationships between elements of the sentence, using syntactic information. But no syntax is necessary to comprehend the signal (a command to press a coded key): "Left, blue." If these stimuli are linguistically mixed, then the first one will demand the use of two language-specific processes to decode the syntax. The second may be comprehended by an alingual word recognition process.

This differentiation is based on the contradictory findings of Dalrymple-Alford and of Macnamara (reviewed in Section 4.2). From the report that reaction times to simple, two-word, signals did not increase with linguistic mixing I have concluded that such messages can be processed without lexical switching, using a direct "look-up" procedure in a vocabulary in which all words are stored without being segregated into separate linguistic compartments.<sup>1</sup> However, a switching of processes

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<sup>1</sup>While stored together, words have markers indicating to which language they belong, and these markers may be used as cues, similarly to taxonomic categories, to facilitate memory searches. Cf. discussion of formal organization in Section 2.11.

must have increased reaction times in the verification of sentences, the grammatical analyzing processes being distinct and functionally separate for each language.<sup>1</sup>

Predictions. The hypothesis states that the comprehension of sentence-structured bilingual messages requires switching, while the comprehension of single or paired words does not. To test this hypothesis comparisons will be made between reaction times to unilingual and to bilingual stimuli. If switching occurs, then it is expected that the bilingual reaction times increase significantly above the unilingual ones.

It is predicted from the hypothesis that reaction times to bilingual word-pairs will be about the average of reaction times to unilingual word-pairs in both languages. This average is the expected reaction time for two-word stimuli, calculated on the basis of performance in each of the languages used.

The reaction times to bilingual sentences are predicted to be above the expected reaction times. The expected reaction times are calculated for bilingual sentences from the two unilingual reaction times. If switching takes place, then it should increase bilingual reaction times above expectation.

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<sup>1</sup>Exceptions include those cases where two languages share a common grammar (see Gumperz, 1967), and where an accomplished bilingual may have developed a less specific, "supralingual," grammar to process both of two closely related languages.

#### 5.42 A hypothesis of delays due to disruption

From the outcome of the experiment with mixed sentences it was thought that other factors than switching may be responsible for increased reaction times. The usual word-to-word expectancies are often violated in the mixed sentences where words from different languages may follow each other. In some cases this may be acceptable, as in the use of foreign loan-words, but often the contravention of the expectancy may cause a disruption in the processing, with the effect of increasing overall reaction time.

Disruption may be eliminated with the presentation of whole sentences. If whole sentences are alternated between languages, then switching must occur after the first sentence is processed and before the processing of the second sentence may begin. The observed reaction time differences should reflect the time requirement of the switching process.

#### 5.5 Outline of experiments

The results of four experimental tasks are reported. Two of these, key-selection and categorization, tested the prediction about word-pairs, and the third, verification of mixed sentences, the prediction about sentence-structured stimuli. The hypothesis of delays due to disruption was tested in the verification of alternated sentences.

The experiments were carried out during the course of two separate studies, one with French-English and the other with Spanish-English bilinguals. These studies overlap inasmuch as the results of the comparable conditions are both discussed together when they are relevant to the same prediction. It should be noted, however, that there were some differences in method as well as in the samples; these are described in the appropriate sections.

The following scheme shows the structure of the two studies:

<u>Hypothesis</u>	<u>Stimulus</u>	<u>Experimental task</u>	
		<u>French study</u>	<u>Spanish study</u>
Single vocabulary	Mixed signals	Key selection	---
	Mixed word-pairs	Categorization	Categorization
Grammar switching	Mixed sentences	Verification	---
Disruption	Alternated sentences	---	Verification

## 6. Tests of the input switch: Responses to word-pairs

The first hypothesis states that there are no language-specific processes in the comprehension of messages which are not in sentence form. The hypothesis may be rejected if we find evidence for the input switch. Such evidence will be the finding of switch time, that is, an increase of reaction time for mixed messages above what is predicted from the reaction times to unilingual messages.

One experiment (Dalrymple-Alford and Aamiry, 1967; described in Section 4.21) failed to find differences between responses to unilingual and mixed stimuli. However, as Macnamara and Kushnir (1971) pointed out, the conclusion that languages are not differentiated in input may not be relevant to the processing of natural language, since the stimuli were limited to a few words indicating location and color. Thus, the subjects performed a rather simple mapping from a total of 24 possible stimuli (six instructions in each of four language combinations) to 6 responses.

In the present study I attempted to present a task which is a better sample of the everyday use of language. The subjects were required to decide whether one stimulus word named a member of the semantic category which was named by the other stimulus word. Thus the stimulus domain could be expanded. Also, the response selection now demanded thorough semantic processing.

It was assumed that these word-pairs would not be submitted to grammatical analyses for comprehension. The format, "Category: Member," did not change throughout the experiment; thus the subjects could establish with the first example that this invariant structure did not contain any information (as syntax in a sentence does) that was not given in the words.

Responses to word-pairs were tested in two tasks. The first, key-selection, task was a replication of the Dalrymple-Alford experiment with a slight change in the apparatus. The second, categorization, task required the matching of category names and member names.

Within each task four conditions were introduced by the language combination of the two stimulus words. In two unilingual conditions both words were in one or the other language; in two mixed conditions the words were in different languages, changed in both directions, from English to French or from French to English.

### 6.1 Key-selection

This task required subjects to press one of six keys in response to two-word signals which specified the location (left or right) and the coded color of the key.

#### 6.1.1 Method

Subjects. Seven native English-speaking and six native French-speaking bilinguals were selected by the criteria that they spent at least one year in the country where their second language was spoken. Two exceptions were made among the English-speaking subjects: both had spent less than one year in France, however, they spoke French daily at home or in graduate school during the past two years.

Stimulus material. The stimuli consisted of two-word signals indicating location (left, right) and color (red, yellow, blue). The signals indicating six possible responses in four language conditions were repeated three times, yielding a total of 72 stimuli in which the first word referred to location and the second to color; another 72

signals had color in the first word and location in the second. The following are examples of the signal types (Location/Color and Color/Location).

English unilingual:	Left - Yellow	Blue - Right
French unilingual:	Droite - Rouge	Jaune - Gauche
English to French:	Right - Bleu	Red - Droite
French to English:	Gauche - Red	Rouge - Left

Eight additional stimuli were prepared for demonstration and practice. The stimuli were typed and then photographed to produce transparencies with white lettering on black background. The order of presentation was randomized under the constraint that not more than three stimuli of the same language type appeared in succession.

Procedure. Subjects were tested individually. First they read a detailed description of the procedure, in both languages. They were then seated before a console on which six spring-loaded telephone-type switches were mounted on a sloping panel, grouped three to the left and three to the right, spaced one inch apart so that the fingers could rest on the keys. The keys were color-coded asymmetrically, that is, in the same order of red-yellow-blue from left to right on both sides. An opaque back-projection screen was placed in a window above and behind the response console; the stimuli were projected from an adjacent room.

After instructions the subjects were given 8 demonstration trials. In each trial a white warning light flashed on the panel 300 msec before the onset of the stimulus. The stimulus remained on the screen until response was made. The next trial was given after a 3 sec interval. Trials were given in series of 36 with a 1 min rest period between series. Each testing session began with the first key-selection task in which the first stimulus-word specified location and the second the color. Then the other tasks (categorization, sentence verification;

described in further sections) were given with 5 min rest periods between tasks. The session ended with the second key-selection task in which the first stimulus word specified color and the second the location.

The timing of presentations and rest periods was controlled by a PDP-9 computer which also recorded on magnetic tape the number of the depressed key and reaction time to the nearest 17 msec. This tape was later processed on an IBM 360/50 computer for statistical analyses.

Data analysis. Incorrect responses were identified and discarded. In this task, as in all others reported in this paper, the percentage of incorrect responses was below 5% of the total number of scores. Each subject's correct response times were grouped by stimulus language type, and means and standard deviations computed for each group. Using Grubbs' (1969) method for single samples the outlying scores ( $p < .05$ ) were identified and excluded from further analyses.

For each subject reaction times to mixed stimuli were predicted from his performance on unilingual stimuli. The average of his two mean reaction times to unilingual stimuli in the two languages was considered to be the predicted reaction time, that is, the expected processing times for each of the two words in the stimulus and response time, without language switching. Since the predicted reaction time was based on the subject's performance in both of his languages it was not necessary to take language dominance into account in further analyses. The predicted reaction time was then subtracted from observed scores to yield, after averaging, the subject's switch time,<sup>1</sup> i.e., the increment

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<sup>1</sup>The formula for the calculation of increments is:

$$S = RT_{\text{mixed}} - \frac{RT_{\text{English}} + RT_{\text{French}}}{2}$$

due to a switching process.

An analysis of variance on all observations combined did not find any difference between word-orders in the stimuli, i.e., whether the signal gave the location first or the color, ( $F = 2.89$ ,  $df = 1$ , 1597; N. S.), nor interaction between word-order and stimulus language type ( $F = 2.47$ ,  $df = 3$ , 1597; N. S.); each subject's scores on both word-orders were combined for further analysis.

These data were considered from two aspects: firstly, whether the processing of mixed signals takes longer than unilingual ones, and secondly, whether there is a significant increase of reaction times to mixed signals above what is predicted.

#### 6.12 Results and discussion

Average reaction times are shown in Table 6.1. Analyses of variance between language conditions were performed for the two native-language groups separately. There were no differences in the French group ( $F < 1$ ),

Table 6.1 Key-selection:  
Average reaction times in msec.

Subjects' language	N	Stimulus language combination			
		Unilingual (native)	Native to foreign	Foreign to native	Unilingual (foreign)
English	7	1069	1134	1170	1175
French	6	1330	1340	1323	1240

but a significant effect was found in the English group ( $F = 5.92$ ,  $df = 3$ ,  $15$ ;  $p < .01$ ). Comparisons by the Newman-Keuls method (Winer, 1962) showed that the French unilingual and the two mixed stimulus types were associated with significantly higher reaction times than the English unilingual ones, but that there were no other differences. Thus, the language effect is attributed to the English subjects' slower performance on French words in both mixed and unilingual stimulus types. Reaction times did not differ significantly between unilingual and mixed stimuli.

In Table 6.2 the averaged increments are shown. None of these values differs significantly from zero ( $t = 1.26$ ,  $df = 6$ , for the English group, foreign-to-native switch;  $t < 1$  for all others).

These results do not show any evidence of the operation of an input switch. Concurring with the findings of Dalrymple-Alford and Aamiry (1967) it may be concluded that the linguistic mixing of input, consisting of two-word signals, does not measurably increase processing time. It is suggested that the responding to simple signals from a limited stimulus

Table 6.2 Key-selection:

Average increments and standard deviations in msec

Subjects' language	N	Direction of change			
		Native to foreign		Foreign to native	
		Mean	S.D.	Mean	S.D.
English	7	1	(37)	44	(92)
French	6	14	(79)	-15	(40)

domain need not rely on language-specific and selectively activated comprehension processes.

The next part of the experiment was designed to require more elaborate semantic processing of the stimulus before response can be made.

## 6.2 Categorization

In this task the two-word stimuli consisted of a category name and the name of a category-member. The subjects were asked to indicate whether or not the name category included the named member.

### 6.2.1 Method

This task was employed in both the French and Spanish studies with certain differences in the method.

Subjects. The French-English bilinguals were the same as described in the key-selection task (Section 6.11). In the Spanish study 8 native English-speakers and 15 native Spanish-speakers took part. They were selected by the criterion of having spent at least one year in a country where their second language was used. The Spanish-speaking group included several subjects who were born in the United States (in New Mexico or Texas), but who were raised in a Spanish-speaking environment. It should be noted that some of the foreign-born subjects showed English linguistic dominance.

A total of 18 Spanish-speakers were tested. However, due to equipment malfunction (unrelated to performance of tasks) more than half of the records of three subjects were lost; their remaining data were discarded.

Stimulus material. The word-pairs were generated from a corpus of nouns limited to the 3000 most frequent words in English, French, and Spanish, based on Eaton's (1967) semantic frequency count. Six category groups of 8 members in each were used to prepare 48 word-pairs in which the named category included the member. There were four groups of 12 word-pairs, one each in English, in French or Spanish, mixed from English to French or Spanish, and vice versa. A set of 48 different word-pairs, in which the named category did not include the member, was generated by mismatching categories and members. Each word appeared only once in each language, and no homonyms were used. The following are examples of the word-pair types:

Unilingual, English, same:	Birds: Eagle
Unilingual, French, different:	Aliments: Lit
Spanish/English mixed, same:	Ropa: Glove
English/French mixed, different:	Foods: Berceau

The full list of stimuli for the French study is given in Appendix A, and for the Spanish study in Appendix B. Eight additional stimuli were prepared for demonstration and practice. Each word-pair was typed in the following format:

Birds	Eagle
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The frame identified the category name which always appeared on the left-hand side, the member name on the right.<sup>1</sup> The word-pairs were photographed to produce white-on-black transparencies. The order of presentation

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<sup>1</sup>This format was used in an attempt to control the sequence of decoding two simultaneously presented words. However, several subjects later reported that they often read the right-hand word (the member name) first.

was randomized under the constraints that not more than three stimuli of the same language combination, nor of the same logic value (same or different) appeared in succession.

Procedure. As in the key-selection task the subjects were tested individually. First they read a detailed description of the procedure in both languages. They were then given a list of all the words used in this task, grouped under the category names, in both languages, and asked to make certain that they knew all the words. From this point the procedures in the French and Spanish studies differed.

In the French study the subjects were tested on this task following the key-selection task and a five-minute rest period. The same response panel was used as in the key-selection task; responses were made on the two outermost keys of the array of six. These keys were marked with plus and minus signs for "same" and "different" responses, with the sides reversed for half of the subjects.

In the Spanish study the apparatus was modified: responses were made on a single spring-loaded key which was to be pressed forward for "same" and toward the subject for "different" responses; the directions were marked with plus and minus signs on the two sides of the key. The physical setting of the Spanish study was also different from the French: the projectors and the recording equipment were in the same room with the subject.

The recording of reaction times was to the nearest 17 msec in the French study and to the nearest msec in the Spanish study.

Aside from these changes the testing schedule and the modes of data analysis were similar to those in the key-selection task (Section 6.11, Procedure and Data analysis).

## 6.22 Results and discussion

Average reaction times are shown in Table 6.3. Analyses of variance between language conditions were performed separately for each group in each study. The native-English groups in both studies showed significant language effects (French study:  $F = 22.09$ ,  $df = 3, 18$ ;  $p < .01$ . Spanish study:  $F = 14.38$ ,  $df = 3, 21$ ;  $p < .01$ ). Subsequent comparisons by the Newman-Keuls method (Winer, 1962) found differences between English unilingual means and mixed and foreign language means. As in the previous task, these differences are attributed to the lack of proficiency of the English-speaking subjects in their second language. The French and Spanish-speaking subjects performed equally well in both languages and on mixed stimuli.

Table 6.3 Categorization:  
Average reaction times in msec

Subjects' language		Stimulus language combination			
		Unilingual (native)	Category=native Member=foreign	Category=foreign Member=native	Unilingual (foreign)
French study:					
English	7	1013	1156	1045	1117
French	6	1190	1162	1143	1132
Spanish study:					
English	8	1128	1322	1259	1461
Spanish	15	1425	1453	1411	1355

Average increments are given in Table 6.4. Three of these values differ significantly from zero. One of these (French study, English group, category=foreign/member=native language combination) is a negative switch time, i.e., the observed reaction times were less than predicted.

The fact that two of the eight groups of increments are significantly different from zero does not allow rejection of the input switch hypothesis, but neither does it offer support to its presence as a universal component of bilingual processing. Further examination of the results is warranted before conclusions may be made.

Table 6.4 Categorization:

Average increments and standard deviations in msec

Subjects' language		Stimulus language combination			
		Category=native Member=foreign		Category=foreign Member=native	
		Mean	S.D.	Mean	S.D.
French study:					
English	7	1 86	(50)	2 -25	(30)
French	6	-5	(66)	-23	(85)
Spanish study:					
English	8	28	(100)	-31	(59)
Spanish	15	3 62	(118)	18	(100)

Results of one-tailed t-tests:

1.  $t=4.55$ ,  $df=6$ ,  $p<.01$
2.  $t=2.20$ ,  $df=6$ ,  $p<.05$
3.  $t=2.03$ ,  $df=14$ ,  $p<.05$

First, the magnitude of the increments should be considered. Previous studies (Macnamara and Kushnir, 1971) found increases of 170 and 210 msec due to language change in whole sentences. Within the framework of the input switch model these increments account for the time requirement of the changing of linguistic systems. The presently found 62-86 msec increments--if accepted as reliable values--could suggest the operation of a different and faster process of system change for non-sentence type input. A closer look at the make-up of the groups unfortunately precludes simple and unequivocal answers. It appears that rather than some groups or some conditions being consistently associated with higher increments, it is due to only a few subjects' exceptionally high values that a group has a significant average.

Perhaps a different statistical approach could yield more information. At issue here is the trade-off of the advantages of two types of data presentation. The grouping of observations of like subjects under like conditions, and the reporting of their averages, offer the convenience of fewer figures and clear summaries; at the same time, as the present experiment illustrates; seemingly clear summaries may be wholly fallacious. Another way of presenting the data is the listing of observations, pooled only at lower levels of classification. The obvious disadvantage here is in the difficulty of gaining a perspective, of recognizing general experimental effects. It is possible, however, to inspect the data for patterns which, if found to be consistent, may describe the experimental situation in more relevant detail. The data of individual subjects should be examined for indications of switching.

Increments of individual subjects are tabulated in Tables 6.5 and 6.6; these figures are the averages of two means each, those for "same"

Table 6.5 Categorization:  
Increments of individual subjects in the French study

Subject	Native language	Stimulus language combination			
		Category=native		Category=foreign	
		Member=foreign		Member=native	
		Mean	S.D.	Mean	S.D.
#1	English	124*	(245)	-40	(180)
#2	"	168*	(280)	-12	(96)
#3	"	78	(380)	-83	(217)
#4	"	43*	(114)	14	(129)
#5	"	86	(261)	-6	(112)
#6	"	13	(261)	-19	(249)
#7	"	96*	(163)	-33	(114)
#8	French	-38	(105)	16	(188)
#9	"	42	(125)	2	(136)
#10	"	10	(556)	-128	(411)
#11	"	63*	(151)	-25	(72)
#12	"	-123	(303)	-109	(256)
#13	"	11	(115)	102	(237)

\* Positive switch times, with  $t$  significant to the 5% level or better, at  $df$  between 19 and 21.

Table 6.6 Categorization:  
Increments of individual subjects in the Spanish study

Subject	Native language	Stimulus language combination			
		Category=native Member=foreign		Category=foreign Member=native	
		Mean	S.D.	Mean	S.D.
#1	English	-78	(273)	-89	(237)
#2	"	-20	(125)	-11	(126)
#3	"	-87	(166)	-83	(222)
#4	"	143*	(338)	35	(399)
#5	"	6	(284)	-12	(218)
#6	"	163*	(178)	32	(194)
#7	"	125*	(274)	-125	(323)
#8	"	-28	(227)	3	(313)
#9	Spanish	119	(448)	-16	(204)
#10	"	-115	(331)	13	(306)
#11	"	55	(459)	116	(321)
#12	"	197*	(362)	-43	(159)
#13	"	318*	(501)	-233*	(432)
#14	"	52	(156)	-1	(249)
#15	"	236*	(241)	-103	(243)
#16	"	4	(404)	212	(548)
#17	"	55	(437)	20	(436)
#18	"	44	(361)	13	(353)
#19	"	-36	(294)	54	(302)
#20	"	66	(381)	-31	(200)
#21	"	22	(317)	-68	(261)
#22	"	42	(261)	-10	(177)
#23	"	-119	(189)	-114	(181)

\* Positive switch times, with  $t$  significant to the 5% level or better, at  $df$  between 16 and 24.

word-pairs and for "different" word-pairs, about 10 observations in each group, with the variances pooled over groups.

The data show that increments do not obtain consistently under any language or logic condition, nor within any native-language group. Furthermore, it appears that three individual subjects, for whom significant average increments were found, do not delay systematically under all conditions. Most of the subjects who delay do so in the category=native/member=foreign language condition; the same subjects then yield negative differences when the language combination is reversed.

A survey of individual means of responses to "same" and "different" word-pairs (not shown) indicates further that subjects with significant increments under one condition of language (i.e., direction of switch) may achieve significance by virtue of high values under one logic condition (i.e., true or false, same or different). For example, Subject #4 in the Spanish study yielded the data in Table 6.7.

Clearly, with only a single component significantly greater than zero at 238 msec, none of the combined means can be considered a reliable estimate of switch time. For the same reason it is meaningless--and actually misleading--to propose group averages as measures of switch times.

One of the group averages of increments (Table 6.3) presents the further problem of a statistically significant "negative switch time," i.e., a reaction time decrease following mixed stimuli. Negative switch times occur frequently in the data of both studies, indicating that averages of unilingual reaction times may underestimate the mixed reaction times. The error may be inherent in the method of predicting. Predicted reaction times have customarily been calculated by apportioning unilingual

reaction times to the particular language segments of the stimulus. This method was followed here, predicting processing times per word in the stimulus. The technique implicitly assumes that both words in the stimulus are processed serially and by like processes. However, the data indicate that the two language combinations are not processed similarly. Increments are observed when the category name is in the dominant language and the member name is in the weak; decreases appear in the other combination. This pattern suggests the presence of distinct processes for accessing category and member names. One suggested explanation points to the difference between mixed reaction times which is consistently to the advantage of the category-foreign combination (Table 6.3): since the

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Table 6.7 Categorization:  
Increments of Subject #4 in the Spanish study

Stimulus Language combination	Logic	Mean	S.D.	N	t-value
Category=native Member=foreign	Same	49	(268)	9	1
	Different	238	(381)	12	2.16*
Category=foreign Member=native	Same	10	(279)	12	1
	Different	59	(491)	12	1
Both switches and logic combined		89	(371)	45	1.59

\*  $t$  significant to 5%

category names are generally of higher frequency in the language, and appeared more frequently in the stimuli, their decoding times are probably shorter than those of member names in the foreign language.

It should also be noted that while in the other experiments the "direction of switch" is mentioned, in the categorization task the term is "language combination," specifying which stimulus element (category or member name) was in which language. This distinction was made since in the categorization task the direction of the language change, or the order of decoding, could not be controlled. An attempt to introduce a sequence through the physical format of the stimuli (Section 6.21) was unsuccessful. Most subjects reported after the experiment that they ignored the "pointer-frame" and the usual left-right direction of reading, and often started with the right-hand word. Sometimes this was done in order to begin with the preferred language, sometimes because the search from member to category names seemed easier. The possibility of such a choice had not been foreseen at the time of designing the experiment; its occurrence demonstrates the difficulty of narrowing the subjects' selection of strategies.

This experiment did not explore questions about the mechanics of semantic categorization. However, without proposing a functional model to describe the underlying processes, it is possible to isolate the language-change effect by subtracting reaction-time components due to other processes.

In the following argument the various processes, subsumed in the categorization task, will be viewed as "black boxes," with the single assumption about their nature being that their time requirements are constant.

Consider the following reaction time components:

$$(1) \quad RT_{dd} = C_d + M_d + V$$

$$(2) \quad RT_{dw} = C_d + M_w + V + S$$

where the unilingual (dominant) reaction time ( $RT_{dd}$ ) consists of the time to access the category name in the dominant language ( $C_d$ ), the time to access the member name in the dominant language ( $M_d$ ), and the verification time ( $V$ ). In the mixed (dominant-to-weak) reaction time ( $RT_{dw}$ ) the member name is accessed in the weak language ( $M_w$ ), and the hypothesized switch time ( $S$ ) is added.

Subtracting (1) from (2) the identical components cancel out, resulting in the language difference and switch time:

$$(3) \quad RT_{dw} - RT_{dd} = M_w - M_d + S_1$$

The same procedure is performed on weak-language unilingual and weak-to-dominant mixed reaction times to yield:

$$(4) \quad RT_{wd} - RT_{ww} = M_d - M_w + S_2$$

The right-hand sides of these two equations are added, canceling out the language differences and resulting in an estimate of the switch time, summed for the two switch directions:<sup>1</sup>

$$(5) \quad (M_w - M_d + S) + (M_d - M_w + S) = 2S$$

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<sup>1</sup>The subscripts for  $S$  and  $S$  in Equations (3) and (4) indicate that the switch times for different combinations--or directions--are not assumed to be identical. The switch time estimate is averaged from two reaction time differences, one of which may be negative (i.e., overall reaction times were less than expected) and not reflect switching at all.

Using the method of this experiment, described above, the estimate of switch times while accessing member names can be obtained from reaction times:

$$(6) \quad S = \frac{(RT_{dw} - RT_{dd}) + (RT_{wd} - RT_{ww})}{2}$$

Similarly, switch time estimates can be made for the accessing of category names:

$$(7) \quad S = \frac{(RT_{wd} - RT_{dd}) + (RT_{dw} - RT_{ww})}{2}$$

These two estimates will, of course, be identical, deriving from the same overall reaction times in which category and member name accessing processes are not separable.

Equations (6) and (7) can now be compared with the formula by which switch times were calculated from predicted reaction times, based on unilingual averages. For mixed stimuli the predicted reaction times were the averages of the two unilingual reaction times:

$$RT_{\text{predicted}} = \frac{RT_{dd} + RT_{ww}}{2}$$

Switch times were calculated by subtracting the predicted from the observed value; switch times for both directions (dominant-to-weak and weak-to-dominant) averaged to yield an estimate of mean switch time:

$$(8) \quad S = \frac{RT_{dw} - \frac{(RT_{dd} + RT_{ww})}{2} + RT_{wd} - \frac{(RT_{dd} + RT_{ww})}{2}}{2}$$

Equation (8) can be reduced and shown to be identical with Equation (6) or (7).

It is proposed that semantic categorization tasks may justifiably be used to test the hypothesis about the existence of an input switch without a more detailed investigation of the categorization process itself. The input switch model (as proposed by Macnamara, and tested here) does not attempt to account for variations in the comprehension process outside those connected with language change. Further research, based on different hypotheses and focused on accessing processes, will have to aim specifically at the identification of cognitive strategies associated with such stimulus attributes as direction of language change, direction of search (to category head or to member), and the truth value of the stimulus item.

### 6.3 Conclusions

In the key-selection task no evidence was found for an input switch. Mixed messages were processed similarly to unilingual ones.

The results of the categorization tasks cannot be interpreted to reject either the single vocabulary hypothesis or the original input switch model. There is no evidence that the input switch is an essential part of the comprehension process in all cases. On the other hand, the finding that some subjects in some situations respond slower than predicted indicates that linguistic mixing of input causes delays in processing. Whether these delays are associated with input switching or some other process cannot be ascertained from the present data. Further conclusions are included in the general discussion in Chapter 8.

## 7. Tests of the input switch: Responses to sentences

The second hypothesis proposed here is a "weak version" of the input switch hypothesis. It assumes that the disambiguation of meaning in a sentence often depends on information given in the relationships among words; to extract this information grammatical analyses may be necessary; processes that perform grammatical analyses are language-specific. Therefore, if input is in sentence form and is switched between languages, the listener must switch processes accordingly. It is predicted that the occurrence of switching results in extra steps in processing and will be manifested in reaction time increases.

Previous studies reported switch times--differences between observed and predicted reaction times--in tasks of comprehension of connected text (Kolars, 1966b) and of verification of sentences (Macnamara and Kushnir, 1971). The following two experiments both employed single sentences as stimuli in verification tasks. First, performance was tested on mixed sentences (in which languages changed in mid-sentence); this task was part of the French study. The second experiment, using Spanish/English bilinguals, tested performance on sentence-pairs where languages changed between sentences.

### 7.1 Mixed sentences

In this task the subjects were asked to read sentences, judge them true or false, and indicate the decision by pressing a key. The stimulus sentences were English, French, or mixed.

### 7.11 Method

Subjects. The same subjects were used as described in Section 6.11 (key-selection task).

Stimulus material. The sentences were generated from a corpus of nouns and verbs, selected from the most frequent 3000 words in both English and French, based on Eaton's (1967) semantic frequency count. The words contained no homonyms.

Seventy-two "true" sentences were constructed, 12 each in English, French, mixed from English to French and vice versa, the switch occurring either before or after the verb. The six groups of 12 sentences were counterbalanced for the number of singular and plural subject nouns, the verbs "be," "have," "can," and a group of such verbs as "wear," "make," "go," etc., and the adjectives "all," "many," and "some."<sup>1</sup> Seventy-two false sentences were constructed by mismatching the subjects and predicates of the true sentences. Each phrase appeared only once in each language. The following are examples of sentence types:

Unilingual, English, true:	A horse is an animal.
Unilingual, French, false:	Le miroir a des écales.
English/French, switched before the verb, true:	Flowers ont des pétales.
French/English, switched after the verb, false:	Le beurre est made from stone.

The full list of sentences for the French study is given in Appendix C.

The set of 144 sentences for testing and 8 additional ones for demonstration were typed and then photographed to produce transparencies

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<sup>1</sup>After the data had been collected a three-way analysis of variance was performed to partition the effects of verb-type, language, and logic value (true or false) across all subjects. There were no significant differences between verb types.

with white lettering on black background. The order of presentation was randomized under the constraint that not more than three stimuli of the same type by language, or by logic (true or false), appeared in succession.

Procedure. Subjects were tested in the same manner as described in Section 6.11 (key-selection task). Responses were made on the two outermost keys of the array of six, used in key-selection. These keys were marked with plus and minus signs for "true" and "false" responses, with the sides reversed for half of the subjects.

The mixed-sentences task was performed after the key-selection task, for half of the subjects following and for the other half preceding the categorization task.

Data analysis. In the case of all but one subject incorrect responses were below 5%. Subject #8 responded wrongly to 5 out of 12 English unilingual stimuli but her error rate and reaction times were average in all other conditions.

Correct response times for each subject were grouped by stimulus type, and means and standard deviations computed. Using Grubbs' (1969) method the outlying scores ( $p < .05$ ) were identified and excluded from further analyses.

Switch times were calculated by the method of mean difference scores, described by Macnamara and Kushnir (1971) with some modification. The unequal proficiencies of a subject were compensated by predicting a reaction time for each sentence. The analysis was performed on the differences between these predicted and the observed reaction times. Predicted reaction times were obtained on the basis of reaction times to unilingual stimuli, from which a mean reaction time per syllable in

each language was assigned to the English and French segments of mixed sentences, in proportion to the number of English and French syllables.

In the present experiment this method was modified. The number of letters, rather than syllables were used to measure the length of a segment. This modification was deemed necessary since regression analyses of unilingual reaction times over stimulus length by syllable failed to find significant correlations; only the letter-count of English sentences correlated significantly with reaction time. Accordingly, the predicted reaction times were computed for each subject from the number of letters in the English and French segments of mixed sentences, weighted by the regression coefficients for each language. Mean difference scores, or switch times, were computed by averaging the differences between observed and predicted reaction times for each subject, then averaging the mean differences for the two language groups separately and in combination.

#### 7.12 Results and discussion

Average switch times are given in Table 7.1. These values are the averages of two means, for true and for false sentences, with the variances of these logical categories pooled to yield a single estimate.

The data do not unambiguously support the prediction that switch times will be observed in sentence processing. Only the French-speaking group shows consistent and significant reaction time increases; the English-speakers have only one significant switch time among the four stimulus types.

The two groups differ further in regard to the effect of the switch direction, that is, whether the stimulus sentence shifted from native

language to foreign, or vice versa. The effect of direction is significant in the English group ( $F = 19.64$ ,  $df = 1, 6$ ;  $p < .01$ ), the foreign-to-native shift being associated with higher switch times. In the French group the tendency appears to be the opposite but the difference is not significant ( $F = 1.43$ ,  $df = 1, 5$ ; N. S.).

There is no significant effect due to the position of the switch, that is, whether the language change took place early in the sentence, before the verb, or later, after the verb (English group:  $F < 1$ ; French group:  $F = 1.77$ ,  $df = 1, 5$ ; N. S.).

The lack of consistency between groups reflects an even greater diversity of patterns in the data of individual subjects. Table 7.2 shows the switch times of each subject. The values are averages of four means, true and false types and before-verb and after-verb switches. Again, as in the categorization task, there is obviously no indication

Table 7.1 Mixed sentences:  
Average switch times and standard deviations in msec

Subjects' language	N	Direction and position of change							
		Native to foreign				Foreign to native			
		Before verb		After verb		Before verb		After verb	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
English	7	-9	(122)	-29	(140)	131*	(135)	24	(116)
French	6	224**	(83)	115**	(87)	100*	(113)	121**	(71)

\*  $t$  significant to the 5% level  
 \*\*  $t$  significant to the 1% level

Table 7.2 Mixed sentences:  
Switch times of individual subjects

Subject	Native Language	Direction of switch					
		Native to foreign		Foreign to native		Combined	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
#1	English	51	(620)	182*	(652)	117	(588)
#2	"	-152	(516)	-30	(645)	-91	(580)
#3	"	-16	(323)	5	(344)	-5	(333)
#4	"	6	(316)	47	(307)	26	(311)
#5	"	-26	(229)	121*	(308)	47	(267)
#6	"	67	(541)	226*	(564)	146*	(552)
#7	"	-67	(212)	-8	(231)	-37	(222)
#8	French	172	(667)	132	(514)	152*	(599)
#9	"	97	(331)	174*	(391)	135*	(363)
#10	"	243	(902)	58	(764)	150	(836)
#11	"	142*	(399)	202*	(613)	172*	(513)
#12	"	100*	(259)	86*	(259)	93*	(259)
#13	"	266*	(564)	10	(399)	138*	(491)

\* Positive switch times, with  $t$  significant to the 5% level or better, at  $df$  between 34 and 47 for individual switches, and between 72 and 92 for combined switches.

of systematic switching for most subjects. For example, only two subjects (Numbers 11 and 12, French group) have significant switch times for changes made in both directions. It must be concluded that the input switch, if there is one, does not always operate and cause delays. This was suggested by Neufeld (1973) who recently tried and failed to replicate the Macnamara and Kushnir (1971) input switch experiment. Neufeld found significant negative switch times, that is, differences where the observed reaction time was lower than what was predicted from unilingual performance. Neufeld speculated that perhaps in some situations (especially when the syntax of one language is not seriously violated by the insertion of foreign words) the whole sentence may be processed as if it were in one language. This explanation is quite plausible in the case of balanced bilinguals who may treat inserted foreign words as guest-words or even as synonyms.

## 7.2 Alternated sentences

This task was designed to test two notions that arose from interpretations of the outcome of the experiments with mixed sentences. Neither of these notions could be properly integrated within the switch concept, and they were not fully formulated as hypotheses. A more complete plan for their testing will be given in the section proposing further research.

The first idea is credited to Neufeld (1973). To restate, it admits the possibility that some mixed sentences may be processed without switching. If the bilingual reader finds in the mixed sentence a foreign word or phrase (or even the whole second segment of the sentence) that appears in a way that does not critically violate the syntax of the language used in processing, then the meaning of the sentence may be

achieved without having to change to other language-specific processes.

The second notion, first proposed here, may be called the "crash hypothesis," a term born of the parlance of computer programmers. The comprehension process is viewed as the execution of a program in which the operations are decoding steps, according to the rules of grammar, and the values given to variables are the words in the sentence. If the given values do not fall within the acceptable range, to which the program's operations are limited, then processing either concludes with a wrong result or simply stops (the program "crashes"). When foreign words are encountered in a sentence, they may be within the acceptable range, that is, they may be admitted as non-foreign (for example, rendezvous, sputnik, or strudel) by English unilinguals. Since bilinguals often accept and use translation equivalents as synonyms, their tolerance of inserted other-language words is even wider. Note that we speak of inserted words! Whether a language shift in a sentence becomes an obstacle depends on how well the other-language part of the sentence can be treated as the insertion of one or more words. The concern here is with those cases where some of the stimulus sentence is not accepted for normal processing. If the processing is not halted, then the result may be wrong. In the recent study incorrect responses were discarded. The main interest is on the event of the processing being disrupted. In this case processing must start again, this time using the program appropriate to the second language. It is proposed that the increases in reaction time, heretofore thought of as switch times, are partially, or perhaps entirely, due to additional steps taken to recover from processing errors, and not due to switching. A proper measure of switch times would have to eliminate the possibility of disruptions in processing by presenting

whole, intact, sentences. These would also serve to ensure that switching occurs. It may be assumed that a sentence which is wholly in one language will be processed according to the grammar of that language. If two sentences in different languages are given in succession, then the reader must switch at the moment when the first sentence is comprehended and before the processing of the second sentence is begun.

Both the non-switch and the "crash" notions suggested the following experimental task. Within each trial two sentences are presented for verification (true or false), one at a time, in succession. As soon as response is made to the first sentence, the second sentence is presented for response. In a unilingual sequence both sentences are in the same language, thus a language switch is not necessary. In a bilingual, or alternated, sequence the second sentence is in a different language from the first, requiring a language switch before the processing of the second sentence may begin. The time it takes to switch is then an added component of the reaction time to the second sentence. Comparisons of reaction times to second sentences in a unilingual versus in a bilingual (alternated) sequence should test whether there is a significant increase which is due to the language switch.

#### 7.21 Method

Subjects. This task was only given in the Spanish study. The subjects are described in Section 6.21 (categorization task).

The data of two subjects are missing from this part of the study. In the case of Subject #11 the preliminary screening for wrong responses and outliers resulted in so many missing values within the same factor and level that no meaningful comparisons could be made. The entire set

of data of Subject #13 was lost due to a malfunction in the recording instrument.

Stimulus material. From the same corpus of words used in the other tasks 15 true and 15 false sentences were generated in English and translated into Spanish. The full list of these sentences is given in Appendix D. A series of 120 sentence-pairs was constructed; there were 60 sentence-pairs in unilingual sequence, 30 with both sentences in English and 30 with both sentences in Spanish; 60 sentence-pairs were in the alternated sequence, 30 of which had English in the first sentence and Spanish in the second, and 30 pairs in the opposite order. None of the pairs contained identical or translation equivalent sentences, nor sentences that were true/false versions of each other. The entire series was randomized with the constraints that no language pattern (i.e., similar sequences, such as English-Spanish following English-Spanish), nor logical pattern (e.g., true-false following true-false) appeared more than twice in succession. Each sentence appeared four times, twice as the first and twice as the second member of a pair; the order of appearance was not balanced. As for previous tasks, the sentences were typed and photographed to produce transparencies with white lettering on black background.

Procedure. The same apparatus and setting were used as described in Section 6.21 (categorization task) for the Spanish study. In each trial a white warning light flashed on the panel 300 msec before the onset of the first, or primer, stimulus sentence. The stimulus remained on the screen until response was made: the key pressed forward if the sentence was true, or pulled back if it was false. Immediately after the response (approximately 15 msec later) the second, or test, stimulus

sentence appeared and remained on the screen until a response to it was made. After a 3 sec interval the next trial began. Trials were given in series of 30, with a 1 min rest period between series.

Data analysis. The first members of sentence-pairs were not included in the analysis since they were used only as primers to establish one language or the other in the first part of each trial. For each subject correct response times of the test sentences (i.e., the second sentence in each pair) were grouped by language and by logic, and means and standard deviations computed for each group. The outliers ( $p < .05$ ) were identified by the usual method (Grubbs, 1969) and discarded.

Missing observations (due to the elimination of wrong responses and outliers) resulted in empty cells in the analysis of variance matrix. The number of empty cells varied between one to three (from a total of 32) for each subject. The matrices were balanced by the insertion of dummy values equivalent to the predicted mean of each empty cell.

It was decided to forego overall analyses since these proved in the preceding to be less informative than individual treatments of the data. The results of each subject were submitted to four-way analyses of variance to partition the effects of language, logic, repetition and sequence. The last two classifications were introduced after the experiment to remove effects which were not counterbalanced by the random order of stimulus presentation.

The repetition factor had four levels, from first to fourth appearance of the given sentence. Since the same sentences appeared twice in the test position, there is a dependency between two levels of the repetition factor. In this design the four possible orders of appearance of the same sentence may be viewed as replications.

The sequence factor classifies four possible patterns of language combinations preceding each test sentence. The following are the four patterns by which English test sentences were classified:

Previous trial		Present trial	
<u>Primer</u>	<u>Test</u>	<u>Primer</u>	<u>Test</u>
1. Spanish	- English	- Spanish	- English
2. English	- English	- Spanish	- English
3. English	- Spanish	- Spanish	- English
4. Spanish	- Spanish	- Spanish	- English

For each language a series of contrasts were tested; there were significant differences between several pairs of patterns. These, however, were not consistent in any direction, nor did they support predictions of possible set effects. For example, it was expected that Pattern #4 would be associated with higher reaction times than Pattern #1, since shifting to English after three Spanish sentences may be more difficult than after only one; in fact, this pattern had the lowest average reaction time for English sentences (its Spanish equivalent did not differ from the other patterns).

The repetition, sequence, and logic factors were included in the individual analyses of variance in order to partition out their effects but no further tests of significance were performed on them. In the case of the repetition factor there is a question of the degrees of freedom for error, which should have been reduced (by as much as half), since there are half as many independent observations as specified by the design; however, this correction would not have changed the value of  $F$  necessary for significance, and it was not applied (the correction would have resulted in an even more conservative test, possibly rejecting some switch times).

For each subject three comparisons were made: (1) for linguistic balance, between reaction times to test sentences in English and Spanish unilingual sequences; (2) for English/Spanish switch time, between reaction times to test sentences in Spanish unilingual sequences and English/Spanish alternated sequences; and (3) for Spanish/English switch time, between reaction times to test sentences in English unilingual sequences and Spanish/English alternated sequences.

#### 7.22 Results and discussion

The results of tests for linguistic balance are shown in Table 7.3. Two of the native-English subjects (#2 and #5) and three of the native-Spanish (#10, #21, and #23) showed no significant differences between the two languages and were classified as balanced. Two native-Spanish subjects performed significantly better on English sentences and were classified as dominantly English-speakers.

Switch times (differences between unilingual and alternated mean reaction times) are given in Table 7.4 where subjects are grouped according to linguistic dominance or balance.

Comparisons of unilingual and alternated mean reaction times yielded two significant differences: Subject #7 showed a 220 msec increase ( $F = 4.78$ ,  $df = 1, 69$ ;  $p < .05$ ) when switching from the dominant to the weak language; Subject #10 performed faster following a dominant-to-weak language shift than on native unilingual-sequence sentences by 167 msec ( $F = 4.23$ ,  $df = 1, 86$ ;  $p < .05$ ). No other differences were significantly greater than zero.

No explanation can be given for either the positive or the negative switch time. The pooling and averaging of the data by any classification would absorb these two extreme values and result in non-significant

Table 7.3 Alternated sentences:

Results of tests for linguistic dominance

(Differences between average reaction times to test sentences in unilingual sequences)

Subject	Native language	Stimulus language		Results of F-tests			Dominant language
		English	Spanish	F	df	p	
#1	English	1038	1163	4.07	1, 84	.05	English
#2	"	905	953	1	1, 58	NS	===
#3	"	1020	1190	9.45	1, 81	.01	English
#4	"	1198	1358	16.92	1, 83	.01	English
#5	"	1229	1159	1.07	1, 81	NS	===
#6	"	1136	1448	28.82	1, 83	.01	English
#7	"	1355	1607	27.18	1, 69	.01	English
#8	"	1056	1368	32.57	1, 65	.01	English
#9	Spanish	1435	1225	15.77	1, 79	.01	Spanish
#10	"	1284	1474	2.20	1, 86	NS	===
#12	"	1315	1133	11.32	1, 85	.01	Spanish
#14	"	1122	972	20.25	1, 84	.01	Spanish
#15	"	1378	1125	29.82	1, 82	.01	Spanish
#16	"	1290	1564	9.88	1, 84	.01	English*
#17	"	1547	1432	5.34	1, 84	.05	Spanish
#18	"	1270	1035	22.51	1, 84	.01	Spanish
#19	"	1024	1476	59.74	1, 80	.01	English*
#20	"	1410	1362	4.56	1, 81	.05	Spanish
#21	"	1493	1653	2.34	1, 85	NS	===
#22	"	1305	1105	37.62	1, 73	.01	Spanish
#23	"	1182	1106	2.36	1, 80	NS	===

=== marks linguistically balanced subjects

\* subjects dominant in non-native language

Table 7.4 Alternated sentences:  
Switch times of individual subjects in msec

Subject	Dominant language	Direction of change	
		Dominant to weak	Weak to dominant
#1	English	-23	6
#3	"	3	45
#4	"	-35	-59
#6	"	90	42
#7	"	220	22
#8	"	159	61
#16	"	-27	99
#19	"	-47	93
#9	Spanish	52	10
#12	"	-87	-65
#14	"	36	19
#15	"	11	77
#17	"	-19	-48
#18	"	9	75
#20	"	77	6
#22	"	39	7
		Native to foreign	Foreign to native
#2	Balanced	-9	44
#5	"	20	-38
#10	"	54	167
#21	"	181	71
#23	"	17	46

differences. Thus, in these results there is no evidence for the input switch in the comprehension of alternated, intact, sentences.

The question arises whether the input switch hypothesis is in firm by these findings. In Table 7.5 the upper confidence limits (95%) of switch times are shown. These figures exclude the 170-200 msec switch time estimate (Macnamara and Kushnir, 1971) for 10 of the 22 subjects if changes in both directions are considered, and for 14 subjects if the limits are averaged. It appears that while there is no conclusive evidence against the existence of an input switch, it is necessary to modify the hypothesis to admit the possibility of switching without delay or of processing without switching. These alternatives will be proposed in the next chapter.

### 7.3 Conclusions

The inconsistency of the data in the mixed sentences task does not allow firm conclusions but points to serious faults in the experimental method. The presentation of mixed sentences may not be the correct technique to measure switch time. The results may be biased unpredictably in opposite directions. Firstly, the presentation of mixed sentences allows processing without switching at least in some instances; thus, reaction times representing both switched and unswitched processing are entered together in the computation of switch times, resulting in large variances. Secondly, when syntactical violations are encountered in mixed sentences, additional correcting processes may be introduced; in these cases switch times may partially represent disruptions in processing.

The task to verify alternated sentences was designed to eliminate these two possible sources of error. Firstly, it necessitated switching

Table 7.5. Alternated sentences:

Upper confidence limits for switch times of individual subjects in msec

Subject	Dominant language	Direction of change	
		Dominant to weak	Weak to dominant
#1	English	108	135
#3	"	118	119
#4	"	62	39
#6	"	238	189
#7	"	389	176
#8	"	314	202
#16	"	134	255
#19	"	70	210
#9	Spanish	202	150
#12	"	32	55
#14	"	120	102
#15	"	108	173
#17	"	116	83
#18	"	94	174
#20	"	170	99
#22	"	124	89
		Native to foreign	Foreign to native
#2	Balanced	61	118
#5	"	110	134
#10	"	188	-33
#21	"	341	224
#23	"	114	139

for all bilingual stimuli; secondly, it avoided violations of grammar by using intact sentences. The effect of the differences between the two tasks, with regards to switching, may be seen from the variances of the individual subjects, shown in Table 7.6. The variances in the alternated sentences task are significantly lower (rank test:  $z = 3.20$ ,  $p < .01$ ), demonstrating the successful separation of different types of processing. The second notion, that switch times may represent disruptions in processing, also appears to be valid in view of the lack of large differences between reaction times in unilingual and alternated sequences.

The overall results of the experiment with alternated sentences do not support the hypothesis that switching of processes (at least of grammatical analyses) is essential for comprehension. Inspection of the data indicates, however, that reaction times do increase in some of the cases; whether the increases reflect switching or delays due to other processes cannot be ascertained.

Finally, mention should be made of one previous study in which the results followed a pattern similar to the present one. Kolers (1966b) performed a series of experiments using connected passages as stimulus material; there were unilingual, alternated (switched at end of sentence), and mixed (switched in mid-sentence) texts. In all aspects of performance (reading speed, accuracy, comprehension) subjects did best on unilingual passages in their native language and second best on alternated passages, followed by mixed passages; the differences between these conditions were significant. Kolers did not separate input and output processes, thus there is no information about the main source of differences. However, his data also suggest that mid-sentence language changes may cause disruptions in addition to, or instead of, setting the input switch.

Table 7.6 Mixed and alternated sentences:  
Estimates of standard deviation for individual subjects in both studies

Mixed sentences			Alternated sentences		
Subject	Native language	S.D.	Subject	Dominant language	S.D.
#1	English	605	#1	English	276
#2	"	600	#3	"	248
#3	"	336	#4	"	222
#4	"	304	#6	"	340
#5	"	301	#7	"	360
#6	"	547	#8	"	312
#7	"	216	#16	"	352
#8	French	561	#19	"	267
#9	"	354	#9	Spanish	318
#10	"	791	#12	"	278
#11	"	466	#14	"	182
#12	"	283	#15	"	268
#13	"	499	#17	"	301
			#18	"	263
			#20	"	216
			#22	"	186
			#2	Balanced	155
			#5	"	205
			#10	"	290
			#21	"	353
			#23	"	231

## 8. General conclusions

In this final chapter I shall restate the major points in the background of this research: the language processing model, findings related to it, and the hypothesis based on its features. After a summary of the results and their interpretations I shall add alternative explanations and secondary conclusions about the theoretical framework and the methodology of the present study. Finally, an alternative model and further research are proposed.

### 8.1 The model and hypothesis

In Chapter 2 a language processing model was proposed. Its principal feature is the alingual mode of comprehension. The model states that the formal aspects of verbal input are secondary, and only of temporary use in processing: newly input and stored information are inter-related on a conceptual level. Consequently, those formal aspects which determine the language of an utterance are irrelevant in the comprehension process.

There is considerable evidence in the literature (reviewed in Chapter 3) that the storage and retrieval of verbally input information are independent of the formal aspects of the input and are determined by the concept-handling capacity of the cognitive system. In all of the reported studies the stimuli were discrete words or word lists. It was concluded that words are stored in a single vocabulary regardless of language, and that the comprehension of discrete words is a direct "look-up" process with no regard to linguistic aspects. Exceptions may be found as the result of special coding of the input language in memory when the experimental task requires this.

The comprehension of connected text and of single sentences was discussed in Chapter 4. The findings were organized around two topics: the problem of simultaneous input in two languages, and the question of system switching for linguistically mixed sentences. In the first case, the evidence agrees with the predictions of alingual processing; the language of an utterance does not sufficiently identify it as the relevant or the competing message; messages are not discriminated by formal, linguistic features but on the basis of meaning. In view of this observation the findings of the language switch experiments are surprising. In these studies the changing of languages within a single input stream appeared to cause delays in comprehension. The delays have been attributed to the operation of an input switch that selectively activated one or another language system in the listener/reader. To accommodate the switch concept I amended the prediction of the alingual model as follows.

In a sentence some of the information is given in the relationships among words; to achieve the correct meaning the sentence must be submitted to grammatical analysis. Since grammars are specific to languages, if the same sentence consists of segments in different languages, then grammars must be changed during processing.

I predicted on the basis of the hypothesis, formulated in Chapter 5, that the mixing of languages within a stimulus item will not cause a delay if the stimulus is not a sentence, but will do so for sentences. These predictions were tested in the three experiments described in Chapters 6 and 7. In addition, a fourth experiment was performed (also reported in Chapter 7) to answer questions that arose from the findings of the mixed-sentence task.

## 8.2 Results and conclusions

### 8.2.1 Responses to word-pairs

Key-selection. The results of this experiment concurred with those of an earlier, similar study: bilingual signals were processed as fast as unilingual ones. Analysis to detect switch times had negative results: there were no increases attributable to switching.

Categorization. Overall averaging resulted in data that agreed with the prediction: there is no evidence of switching among grouped subjects. In view of the diversity in the performance of individual subjects, however, it became apparent that much of the information from this experiment may be obscured by averaging. From the results of tests made on data subdivided by logic (same or different items in the stimulus) and direction of change (first to second word changing from native to foreign language or vice versa) the following conclusions were made.

In the two subgroups in which switch times were significant the switch times averaged 70 msec. If this is accepted as a reliable value, then it may indicate a language system change on a much smaller scale than implied by the input switch hypothesis (for which the evidence was an average 170 msec switch time). This estimate of switch time could be accepted only with very strong reservations, and only within the limited scope of the input switch model. It does not, in fact, represent a processing event that is regularly, and repeatably, occurring in the comprehension of bilingual stimuli. Significant and uncommonly high reaction times increases were recorded for but a few subjects; since none of these subjects (except one) yielded such increases in both stimulus conditions (by direction of change), neither their individual scores, nor the averages, may be associated causally with the mixing of languages in input.

I shall offer two conclusions, one within the input switch model, and one that rejects the usual methodology.

In terms of the input switch model the experiments with word-pairs found no evidence of switching. In a more general context the pattern of the data clearly renders the averaging method unacceptable, being uninformative at best, but possibly misleading as well.

#### 8.22 Responses to sentences

Mixed sentences. In this experiment the preliminary processing of the data already raised doubts about the technique adopted by investigators of the input switch. In the previous studies (Macnamara and Kushnir, 1971; Neufeld, 1973) the predicted reaction times to bilingual stimuli were calculated from unilingual reaction times assigned by the number of syllables in the mixed sentences. I did not find significant correlations between reaction time and stimulus length in syllables. A second regression analysis resulted in one significant correlation, in the case of English sentences responded to by English-speakers, between reaction time and the number of letters in the stimulus sentence. As a compromise, and for lack of any other suggested technique, the letter count was accepted as the basis of prediction of individual reaction times.

The results are again ambiguous. The data from the French-speaking subjects agree with the predictions of the input switch model and of the ailingual model (both predicting switching for sentence stimuli). The English-speakers failed to show significant switch times in three out of four conditions, and no switch time at all when averaged over conditions.

Again, similarly to the categorization task, the switch times do not consistently demonstrate a tendency for subjects to switch under all

conditions. The significant switch times are averages of very high differences (between observed and predicted times) and practically zero or even negative switch times.

On the premises of the input switch model and its modified version, hypothesizing a grammar switch, the prediction is fulfilled by the averaged results. I do not unequivocally state, however, that a switch of language systems, or of grammars, occurs as a routine step in the process to comprehend mixed sentences. Delays in processing were observed but not necessarily due to switching. Within the language or grammar switch models I cannot account for the performance of those subjects who either did not show processing delays, or responded faster to bilingual stimuli than expected.

Alternated sentences. This experiment attempted to answer two objections against the mixed-sentence paradigm, namely, that some mixed sentences are processed without switching, and that mixed sentences cause disruptions which delay processing and could be falsely interpreted as switching.

There could be no clear evidence of having overcome the first objection (made by Neufeld, 1973). It can only be assumed, reasonably, that an English sentence will not be processed using Spanish grammar, or vice versa. There is a major difference, however, between the mixed and alternated sentences experiments in the variances of individual reaction times. The high variances in the mixed sentence experiment could well be attributed to the presence of two different types of responses within the same condition: processing with or without switching. The results of the alternated sentences experiment imply, by their lower variance, that processing was more similar for all stimuli.

The second objection had its source outside the switch concept. It was felt that the word-to-word expectancies in a mixed sentence were violated more than by the linguistic change: the mixing produced unusual, badly-formed, sentences with which neither grammar could readily cope. Even if switching did not take place (the other-language segment being treated as an insertion acceptable to bilinguals), the comprehension process broke down temporarily. This event could invoke other processes ("error/restart" routines) to correct irregularities in the syntax. Although no specific predictions were made, the language processing model outlined earlier (Chapter 2) did point to such components in the recognition process. There I postulated a Grammatical Processor which, in order to verify the first hypothesized meaning of a sentence, will transform ungrammatical phrases to approximate a kernel sentence which can then be tested as an acceptable message. This process is analogous to those phonological transformations that are necessary for utterances in an unfamiliar accent to be understood. In the case of mixed sentences it is quite plausible that corrections need to be made before the meaning is obtained; possibly, translations may be required but there is no evidence of that, nor does intermediate translation fit into this particular model.

The results of the alternated sentences experiment show that when the source of disruption is eliminated, there are no delays in processing that may be interpreted as switch times. The language switch concept could lead to these conclusions: a failure to detect switch times must imply that the switching of language systems, or of grammars, does not require appreciable time, or that a general and not language-specific grammar system could be used to analyze sentences in both languages. Neither of these conclusions are acceptable.

It appears that no reasonable explanations could be made on the basis of the predictions of a switch model.

### 8.23 Conclusions about the switch concept

The starting point of this research may be placed at the contradictory findings of several experiments in bilingual behavior. Investigations of serially mixed input (Dalrymple-Alford and Aamiry, 1967; Macnamara and Kushnir, 1971; Neufeld, 1973), and interpreted within the language switch concept, concluded that bilingual stimuli were processed either entirely without linguistic distinction, or with switching language systems, or as if they were in one language. Experiments in which two languages were used simultaneously in input (Treisman, 1964a; Lawson, 1967) demonstrated that enough interference between languages took place to question the efficiency, or indeed the existence, of an input switch. My experiments attempted to find the cause of the delay in processing that was observed with serial bilingual input. Implicit in their design was the language switch concept; a certain type of input--word-pairs--were held to be processed ailingually, while another type--in sentence form--required the switching of grammars. Since the last experiment with sentences indicated processing without switching I cannot claim that there is a distinction due to the structure of the input message. The only meaningful difference between conditions was the one between stimuli that could be the source of disruption in processing and those that did not. Consequently, reaction time increases may not be identified as switch times. In the final conclusion the concept of switching is found to be without sufficient support and rejected.

### 8.3 Comments on grouping subjects by language

A belatedly recognized problem in this research had to do with the identification of subjects by language as it has been done in all the studies reported in the literature. The question arose whether it is sensible to group subjects by their native language, and to discuss switch-direction in terms of "native-to-foreign" or "dominant-to-weak," in cases where the subject is considered to be balanced and assumed to have no preference for either of his languages.

Since the French study included replications of other experiments (key-selection and mixed sentences) it was decided to follow the convention. Group averages were presented separately for native-English and native-French subjects; in the categorization task of the study, subjects were grouped similarly.

I wish to emphasize that the use of this method here does not mean uncritical acceptance of the established practice, but was thought to be necessary to facilitate comparisons between the present data and those of others. Elsewhere in this paper (Sections 6.22, 7.21, 8.4) I argued against the use of group averages to describe results; the danger of obscuring information by averaging is increased further if the grouping is done on possibly false grounds.

To demonstrate the difficulty of the situation a survey of language dominance is shown in Table 8.1. In the sentence task three of the native-Spanish subjects were balanced (i.e., with no significant difference between average reaction times to English and Spanish unilingual stimuli), eight were Spanish-dominant, and two had reversed language preference, proving to be English-dominant. Supposing that these subjects are grouped

Table 8.1 Language dominance in two tasks  
in the Spanish study

Subject	Native Language	Dominant language in task	
		Categorization	Alt. sentences
#1	English	English	English
#2	English	===	===
#3	English	English	English
#4	English	English	English
#5	English	===	===
#6	English	English	English
#7	English	English	English
#8	English	English	English
#9	Spanish	===	Spanish
#10	Spanish	===	===
#12	Spanish	English*	Spanish
#14	Spanish	===	Spanish
#15	Spanish	English*	Spanish
#16	Spanish	===	English*
#17	Spanish	===	Spanish
#18	Spanish	===	Spanish
#19	Spanish	English*	English*
#20	Spanish	===	Spanish
#21	Spanish	===	===
#22	Spanish	===	Spanish
#23	Spanish	===	===

=== marks linguistically balanced subjects

\* subjects dominant in non-native language

according to dominance, and not by native language, there is still the problem of classifying the balanced subjects. Further, we find that in the categorization task neither dominance, nor native language, could be considered: while 10 subjects are balanced, three are dominant in their non-native language. Also, note that two subjects actually reverse language dominance between the two tasks.<sup>1</sup>

One solution to the problem could be more stringent sampling to include the data of only balanced subjects in the analyses. This approach, of course, is expensive in terms of effort, since language dominance or balance may be established only after gathering all the data in all the experimental tasks. Pre-experimental tests of dominance cannot be relied upon unless the task in them is identical to that used in the experiment. Then the question would remain whether to include subjects who are balanced on a pre-test and dominant on an experimental task, or differ from task to task (in the present study only 9 of the total of 36 subjects were found to be balanced across all tasks; cf. Table 8.1). The other solution is to accept the method of individual analysis, as demonstrated in the discussion of the alternated sentences task. Without averaging there is no need to attempt to form homogeneous groups; it should be recognized that between-subject differences in language use render such attempts futile.

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<sup>1</sup>The subjects live in a predominantly English-speaking environment. It is expected that the lack of balanced exposure to both their languages can result in differences in proficiency not only between languages but between the various cognitive modes in the comprehension of word-pairs and sentences. As well, dominance may vary between semantic domains that are used to different extents.

#### 8.4 Alternative explanations and proposed research

It was said in a preceding section that neither an instantaneous switch, nor an alingual grammar could be accepted as the explanation for those instances where bilingual messages were processed as fast as unilingual ones. In these cases the only alternative explanation that can be suggested is that in bilinguals both language systems, or grammars, may be simultaneously available. The theoretical frame of reference for this notion is the hypothesis of a limited capacity central system.

The concept of selectively activated language systems, and its product, the input switch model, were based implicitly on the features of a single-channel central mechanism (cf. Broadbent, 1958). In this system information must pass through a single central channel; while the channel is occupied, other information is held in buffers to await processing. Thus, processing is necessarily serial and only one process may be active at any time. Language-specific comprehension processes then must be similarly serial. The input switch hypothesis added the corollary that the changing of processes requires time, as the first process must clear the central channel before the second can be initiated.

More recently hypotheses of distributed or divided attention have been advanced (cf. Moray, 1967), allowing parallel processing in multi-channel or "widened" channel central systems. The alternate model of bilingual comprehension I am going to propose is based on the hypothesis due to Kahneman (1973). The hypothesis states that parallel processing takes place in a number of undifferentiated units; to each of these a certain amount of "effort" (or attention) is allocated as the task demands; the total amount of effort available is limited. This principle

permits the comprehension of two languages simultaneously as long as the limited capacity of the central system is not exceeded. The allocation of effort to process in one or in both languages is directed by the demands of the task. If a language change is not expected, then effort is allocated to a certain number of processing units. Each of these units, or group of units, performs--depending on complexity--one or more decision processes (corresponding to grammar rules) which analyze the input. If a language change is expected, or if two languages appear in input, then the effort is shared among several groups of units; this allocation may be maintained continuously and need not be changed at each language change, thus performance is not interrupted. It should be noted, however, that the total amount of available effort is finite. If the limit is exceeded, then the comprehension process may break down, slowing or disrupting performance. Also, when effort is spread among many units to handle multilingual input, then performance may suffer. There is a certain cost, in terms of effort, of maintaining processing in two languages, with implications toward the level of efficiency in multilingual performance. Future investigations of this aspect could make significant contributions to the solutions of problems in the education of bilinguals, and in related areas.

In closing I shall iterate earlier comments on the soundness of the data-averaging method. The traditional technique has been frequently blamed with obscuring individual differences. In the analysis of information processing the potential damage is even greater. When an hypothesis calls for the testing of certain differences the experimenter may make conclusions on the basis of mean scores which are the products of several, possibly quite different, processing modes. There may be strong

interactions between stimulus conditions and processing modes which will be undetected, and which could falsify results. For example, the data in the categorization task in this research indicates that different processes may have taken place when the category name was in the subject's dominant language and when it was in the second language. Whether the difference lay in the inclusion of a translating step or in the differences between the association hierarchies of the two languages, or were due to other factors, could not be ascertained from these data. But future research, more specifically directed toward the isolation and the identification of processing modes (cognitive strategies), must be designed to separate data according to processes used, rather than by experimental treatments and/or subject groups established a priori. In practical terms, this criterion calls for the matching of reaction time distributions of individuals against experimental factors; more generally, we must verify that our hypothesis asks questions about real events.

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## Appendix A.

Stimulus material for the categorization task  
in the French study

Same, unilingual, English word-pairs

birds: eagle	clothes: hat
birds: chicken	clothes: coat
foods: bread	animals: horse
foods: meat	animals: goat
furniture: clock	body: arm
furniture: bed	body: eye

Same, unilingual, French word-pairs

oiseaux: canard	vêtements: jupe
oiseaux: hirondelle	vêtements: soulier
aliments: oeuf	animaux: chien
aliments: miel	animaux: vache
meubles: chaise	corps: pied
meubles: glace	corps: main

Same, mixed, English-French word-pairs

birds: corbeau	clothes: botte
birds: oie	clothes: chemise
foods: sucre	animals: cochon
foods: lait	animals: ours
furniture: volet	body: tête
furniture: bureau	body: bouche

Same, mixed, French-English word-pairs

oiseaux: owl	vêtements: glove
oiseaux: turkey	vêtements: stocking
aliments: apple	animaux: rabbit
aliments: butter	animaux: wolf
meubles: couch	corps: finger
meubles: cradle	corps: ear

Different, unilingual, English word-pairs

birds: chair	clothes: crow
birds: skirt	clothes: egg
foods: shoe	animals: foot
foods: desk	animals: mirror
furniture: duck	body: honey
furniture: hand	body: cow

Different, unilingual, French word-pairs

oiseaux: horloge	vêtements: poulet
oiseaux: chapeau	vêtements: oeil
aliments: manteau	animaux: bras
aliments: lit	animaux: pomme
meubles: aigle	corps: chèvre
meubles: pain	corps: lapin

Different, unilingual, English-French word-pairs

birds: cheval	clothes: dindon
birds: gant	clothes: beurre
foods: berceau	animals: bas
foods: doigt	animals: oreille
furniture: hibou	body: loup
furniture: viande	body: canapé

Different, unilingual, French-English word-pairs

oiseaux: sugar	vêtements: goose
oiseaux: head	vêtements: bear
aliments: boot	animaux: shirt
aliments: shutter	animaux: mouth
meubles: dog	corps: swallow
meubles: milk	corps: glove

## Appendix B.

Stimulus material for the categorization task  
in the Spanish studySame, unilingual, English word-pairs

birds: eagle	clothes: hat
birds: chicken	clothes: coat
foods: meat	animals: horse
foods: bread	animals: goat
furniture: clock	body: arm
furniture: bed	body: eye

Same, unilingual, Spanish word-pairs

ave: pato	ropa: falda
ave: golondrina	ropa: zapato
comida: huevo	bestia: perro
comida: miel	bestia: vaca
muebles: silla	cuerpo: cuello
muebles: espejo	cuerpo: mano

Same, mixed, English-Spanish word-pairs

birds: cuervo	clothes: bota
birds: ganso	clothes: camisa
foods: azúcar	animals: cerdo
foods: leche	animals: oso
furniture: cortina	body: cabeza
furniture: escritorio	body: boca

Same, mixed, Spanish-English word-pairs

ave: owl	ropa: glove
ave: turkey	ropa: stocking
comida: apple	bestia: rabbit
comida: butter	bestia: wolf
muebles: couch	cuerpo: finger
muebles: cradle	cuerpo: ear

Different, unilingual, English word-pairs

birds: chair	clothes: crow
birds: skirt	clothes: egg
foods: shoe	animals: foot
foods: desk	animals: mirror
furniture: duck	body: honey
furniture: hand	body: cow

Different, unilingual, Spanish word-pairs

ave: reloj	ropa: pollo
ave: gorra	ropa: ojo
comida: gaban	bestia: brazo
comida: cama	bestia: manzana
muebles: aguilá	cuerpo: cabra
muebles: pan	cuerpo: coñejo

Different, mixed, English-Spanish word-pairs

birds: caballo	clothes: pavo
birds: guante	clothes: mantequilla
foods: cuna	animals: media
foods: dedo	animals: oido
furniture: buho	body: lobo
furniture: carne	body: mesa

Different, mixed, Spanish-English word-pairs

ave: sugar	ropa: goose
ave: head	ropa: bear
comida: boot	bestia: shirt
comida: curtain	bestia: mouth
muebles: dog	cuerpo: pig
muebles: milk	cuerpo: swallow

Demonstration material

tools: hammer	herramienta: martillo
vegetables: cebolla	legumbres: onion
tools: cebolla	herramienta: onion

## Appendix C.

Stimulus material for the sentence verification task  
in the French study

True, unilingual, English sentences

A horse is an animal  
The chimney is on the roof  
The sun is in the sky  
The oxen have long horns  
Mirrors can break easily  
The shoulders are below the neck  
All newspapers have pages  
All chickens have two wings  
Many children go to school  
Many churches have spires  
Some doves live in the city  
Some people wear eyeglasses

True, unilingual, French sentences

On écrit sur le bureau  
Une chaise a des coussins  
Un étang est un petit lac  
Les oiseaux peuvent voler  
Les vents forts font la tempête  
Les abeilles sont menues  
Tous les chiens ont quatre pattes  
Toutes les pommes ont des pépins  
Bien des plantes sont vertes

Bien des ponts ont des piles

Quelques chapeaux sont noirs

Quelques hommes portent des bijoux

True sentences, switched from English to French before the verb

The blanket couvre le lit

Butter est un genre de graisse

A brook est un petit courant

Castles ont bien des chambres

Factories ont des souches

Flowers ont des pétales

All ducks peuvent nager

All rocks sont de la pierre

Many ships traversent la mer

Many trees ont des branches longues

Some sheep pourvoient la laine

Some foods sont servis chauds

True sentences, switched from English to French after the verb

A rabbit has oreilles longues

The grass grows dans le jardin

The rain falls des nuages

Eagles can bien voir

Rivers flow dans les vallées

Carpets are sur les planchers

All potatoes are légumes

All monkeys are enjoués

Many shirts have manches courtes

Many shoes have talons hauts .

Some clocks are en avance

Some cars have trois roues

True sentences, switched from French to English before the verb

Un fusil is a weapon

La chandelle gives light at night

Le poisson has scales

Les poêles are in kitchens

Les bateaux float on water

Les portes can be locked with keys,

Tous les verres are breakable

Toutes les maisons have walls

Bien des peintures are framed

Bien des salles have windows

Quelques chats have short tails

Quelques bouteilles contain wine

True sentences, switched from French to English after the verb

\*La neige est very cold

Le pain est made of flour

Une barbe croît on the chin

Les épées ont steel blades

Les coqs chantent in the morning

Les petites villes ont few streets

Tous les oeufs ont yellow yolks

Toutes les oies ont feathers

Quelques livres sont handwritten

Quelques jupes sont made of wool

Bien des vaches peuvent give milk

Bien des ours aiment honey

False, unilingual, English sentences

A desk is for cooking

The snow is served in dishes

A painting has many rooms

The stoves are small mountains

Houses are a kind of fat

The chairs are in the cloud

All bridges wear jewelry

All bottles have four legs

Many birds are raised for wool

Many ponds have big pillows

Some dogs grow long branches

Some small towns cover the bed

False, unilingual, French sentences

Le miroir a des écales

La cheminée est une bête

Un navire a des cornes longues

Les épaules contiennent du vin

Les enfants ont des fleches

Les boeufs ont deux ailes

Tous les châteaux ont des plumes

Tous les ruisseaux sont jaunes

Bien des fleurs ont des fenêtres

Bien des canards sont des armes  
 Quelques chevaux portent des lunettes  
 Quelques gens ont trois jambes

False sentences, switched from English to French before the verb

An apple est dans le ciel  
 Bread a une queue courte  
 The candle va à l'école  
 Strong winds peuvent donner du lait  
 Rifles sont faits de farine  
 The rooms sont au-dessous du cou  
 All hats sont dans la cuisine  
 All geese habitent dans la ville  
 Many fish ont de la laine  
 Many books sont sur le toit  
 Some glasses ont des pages  
 Some boats sont sur le menton

False sentences, switched from English to French after the verb

A rooster has lame d'acier  
 The sword can flotter sur l'eau  
 Beer is écrite à la main  
 Beards grow dans les rues  
 The bees give lumière  
 Vegetables are dans les cadres  
 All plants are fermées à clef  
 All cows can lire des journeaux  
 Many people have trois coudes

Many eggs have des fils aigus  
 Some skirts have bien des murailles  
 Some bears go à l'église

False sentences, switched from French to English before the verb

Un aigle is a little stream  
 L'horloge has tall smoke-stacks  
 La couverture is served hot  
 Les pommes de terre have petals  
 Les arbres sing in the morning  
 Les souliers can see well  
 Tous les lapins cross the sea  
 Toutes les autos have long sleeves  
 Bien des singes have long ears  
 Bien des tapis wear high heels  
 Quelques chemises are playful  
 Quelques aliments can fly

False sentences, switched from French to English after the verb

Le beurre est made out of stone  
 La roche a many bubbles  
 Un mouton peut make a storm  
 Les usines sont in the lake  
 Les rivières coulent on the floor  
 Les colombes sont made of wood  
 Tous les poulets peuvent to swim  
 Tous les couteaux ont many seeds  
 Bien des dents poussent in gardens

Bien des rideaux sont silver

Quelques paniers sont needles

Quelques manteaux ont kittens

## Appendix D.

Stimulus material for the sentence verification task  
in the Spanish studyTrue English sentences

A horse is an animal  
The chimney is on the roof  
Many children go to school  
Some people wear eyeglasses  
The blanket covers the bed  
Butter is a kind of fat  
Many ships cross the sea  
The rain falls from the cloud  
The rivers flow in valleys  
The grass grows in the garden  
Potatoes are vegetables  
A rifle is a weapon  
Candles give light at night  
The boats float in water  
Glasses are breakable

True Spanish sentences

El caballo es un animal  
La chimenea está en el techo  
Muchos niños van a la escuela  
Algunas personas usan lentes  
La manta cubre la cama  
La manteca es grasosa

Muchos barcos cruzan el mar  
 Las nubes dan lluvia  
 Los ríos corren por valles  
 El césped crece en el jardín  
 Las papas son vegetales  
 La escopeta es un arma  
 Las velas alumbran de noche  
 Los botes flotan en el agua  
 Los vidrios se rompen.

False English sentences

A horse is a blue sky  
 The chimney has two wings  
 Many children have petals  
 Some people wear long horns (have)  
 The blanket shines in the dark  
 Butter is a kind of paint  
 Many ships fall from the clouds  
 The rain is a little chain  
 The rivers are on the roof  
 The grass travels on tracks  
 Potatoes have many pages  
 The rifle plays the piano  
 Candles are made of water  
 The boats are a kind of fat  
 Glasses grow in the ground

False Spanish sentences

El caballo es azul

La chimenea tiene alas

Los niños tienen pétalos

La gente tiene cuernos

La manta brilla de noche

La manteca es de pintura

Muchos barcos caen del cielo

La lluvia es una cadena

Los ríos están en el techo

El césped va por las vías

Las papas tienen páginas

El cañón toca el piano

Las velas son de agua

Los botes son de grasa

El vidrio crece en la tierra